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Barriers to industrial energy efficiency: A literature review

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Steve Sorrell
Sussex Energy Group, SPRU
University of Sussex

Alexandra Mallett
Sussex Energy Group, SPRU
University of Sussex

Sheridan Nye
Sussex Energy Group, SPRU
University of Sussex

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Executive summary

There is considerable technical potential for improving industrial energy efficiency and the economics appear favourable, even without putting a price on carbon emissions. Such improvements frequently involve the adoption of established technologies whose performance is well proven and which involve relatively little technical risk. However, it has long been recognised that numerous 'barriers' inhibit the adoption of such technologies, such as lack of information, shortage of trained personnel and limited access to capital. In particular, the adoption of such technologies may be associated with various 'hidden costs' that are difficult to capture within energy-economic models. But while there is a general consensus that an energy efficiency 'gap' exists, and that policy options to overcome this gap need to be identified and acted upon, there is considerable debate over the most effective approach.

This report has been prepared as background to the to the proposed UNIDO report "***If industrial energy efficiency pays, why is it not happening?"*** The objectives are to: identify the nature, operation and determinants of different barriers to the adoption of energy efficient technologies in industry; assess the prevalence and relative importance of these barriers in different contexts; and provide a springboard to determine where to most effectively address policy efforts. A companion report examines policy options for developing countries in more detail (Mallett, *et al.*, 2010).

This report is based upon earlier work by Sorrell *et al.* (2004), together with a review of 160 recent studies of energy efficiency drawn from both the academic and 'grey' literature. The focus throughout is upon energy efficiency in the industrial sector, although some of the studies also include the public and commercial sectors. The report includes quantitative summaries of the results of these studies, together with more detailed examination of those studies which evaluate the relative importance of barriers. Full details of the studies reviewed are contained in an Access database which is available on request.

Main findings

The concept of a barrier to energy efficiency is both confused and contested. Although the term is widely used, there is little consensus on how barriers should be understood, how important they are in different contexts, and how (if at all) they should be addressed. Many authors distinguish between barriers and market failures and recognise that some provide no grounds for policy intervention while others may prove too costly to overcome. However, this perspective tends to treat market failures as absolute, whereas in practice they are relative. It also tends to ignore barriers which are internal to organizations and adopts an unrealistic model of individual rationality.

The classification of barriers to energy efficiency used in this report draws upon orthodox, transaction cost and behavioural economics and is summarized in Table E.1. It is argued that the barriers are to some extent interdependent and may manifest themselves in a number of different ways (e.g., technical versus market risk). Also, the relative importance of each barrier may vary between different technologies and organizations and several are likely to coexist.

Table E.1 A taxonomy of barriers to energy efficiency

Barrier	*Claim*
Risk	The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because energy efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons
Imperfect information	Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market.
Hidden costs	Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information.
Access to capital	If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.
Split incentives	Energy efficiency opportunities are likely to be foregone if actors cannot appropriate the benefits of the investment. For example, if individual departments within an organization are not accountable for their energy use they will have no incentive to improve energy efficiency
Bounded rationality	Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentives.

Despite the lack of rigour and consistency in the empirical literature, the following general conclusions may be drawn:

Hidden costs are real, significant and form the primary explanation for the 'efficiency gap'. These costs frequently outweigh the potential saving in energy costs - especially in SMEs with low energy intensity. What remains in dispute is the extent to which such costs may be cost-effectively reduced by organizational initiatives, public policy or a combination of the two. This issue needs to be resolved by more rigorous research that includes comparative studies of 'good' and 'bad' performers.

The neglect of energy efficiency opportunities is overdetermined: Hidden costs generally coexist alongside one or more of the other barriers in our taxonomy, with the result that the neglect of energy efficiency opportunities becomes overdetermined. Hence, the key issue is not so much the relative importance of different barriers, but their cumulative effect. Initiatives to encourage cost effective investments will need to understand and address several aspects of the problem if they are to be successful.

Barriers to energy efficiency in developing countries are similar to those in developed countries, but more pronounced. Problems of lack of information and skills are widespread in developing countries and inadequately addressed through public policy, and difficulties in accessing capital are very common, especially for smaller firms. While this is partly a consequence of hidden costs, it tends to be exacerbated by the deficiencies of the financial sector, including more limited knowledge of technical risks and opportunities combined with trade and investment policies that restrict access to foreign capital. These problems should be a priority for reform, alongside the removal of energy subsidies which undermine the economic case for improved energy efficiency.

A targeted policy mix is required. Barriers to energy efficiency are multi-faceted, diverse and often specific to individual technologies and sectors. This implies that effective policy solutions will need to address the particular features of individual energy service markets, the circumstances of different types of energy-using organization, and the multiple barriers to energy efficiency within each. It is likely that a mix of policies will be required, in which several different initiatives work together in synergy. The basic elements of this mix are well-established and include best practice schemes, demonstration projects, training initiatives, market-based instruments, labelling schemes and minimum standards for the energy efficiency of equipment. The costs and benefits of these individual instruments will require careful analysis, as will the overall coherence of the mix. But to date, researchers have paid too much attention to modelling what could be achieved and too little attention to evaluating what policy has (or has not) achieved - and why. Hence, much greater priority needs to be given to policy evaluation.

1 Introduction

There is considerable technical potential for improving industrial energy efficiency and the economics appear favourable, even without putting a price on carbon emissions (IPCC, 2008). Such improvements frequently involve the adoption of established technologies whose performance is well proven and which involve relatively little technical risk. Many studies suggest that these technologies are highly cost-effective, with risk-adjusted rates of return greatly exceeding the anticipated cost of capital (Geller, *et al.*, 2006; IPCC, 2008; Krause, 1996; Lovins and Lovins, 1997). Even greater savings can be realised in developing countries where old, inefficient technologies are commonly used. Savings may also be made through optimising system design and improving operational and maintenance procedures while many technologies have productivity benefits that extend well beyond energy-saving (Worrell, *et al.*, 2003).

However, numerous 'barriers' inhibit the adoption of such technologies, such as lack of information, shortage of trained personnel and limited access to capital. In particular, various 'hidden costs' can make such technologies more costly than they first appear. But while there is a general consensus that an energy efficiency 'gap' exists, and that policy options to overcome this gap need to be identified and acted upon (Brown, 2001), there is considerable debate over the most effective approach.

This report has been prepared as background to the to the proposed UNIDO report "***If industrial energy efficiency pays, why is it not happening?***" The UNIDO report seeks to make the case that: i) a variety of barriers prevent industry from adopting cost-effective energy efficient technologies, ii) these barriers can be overcome through a variety of policy interventions; and iii) the potential of these interventions has yet to be fully explored in developing countries.

The objectives of this background report are to: identify the nature, operation and determinants of different barriers to the adoption of energy efficient technologies in industry; assess the prevalence and relative importance of these barriers in different contexts (particularly industrialised versus developing countries; energy-intensive versus non-energy-intensive industries; and Small and Medium Enterprises (SMEs) versus large companies); through this exercise, provide a springboard to determine where to most effectively address policy efforts.

The report builds upon an earlier study of barriers to energy efficiency by Sorrell *et al.* (2004). It seeks to update this by summarizing the results of more recent literature, focusing in particular upon studies from developing countries. The report reviews both academic and 'grey' literature concerning energy efficiency in industry, paying particular attention to those few studies that use either statistical analysis or case study research to establish the relative importance of different barriers.

The structure of the report is as follows. Section 2 provides some basic definitions and summarizes the approach taken, including how the empirical literature was identified and classified. Section 3 describes the nature and operation of six different barriers to energy efficiency in some detail, using a taxonomy developed by Sorrell *et al.* (2004). This taxonomy has since been widely employed in the empirical literature (Masselink, 2007; Rohdin, *et al.*, 2007) and many of the most commonly cited barriers to energy efficiency can be interpreted within this framework. Section 4 summarizes the main findings from the empirical literature, including the most commonly cited barriers to energy efficiency and how these vary from one context to another. Section 5 looks in more detail at a sample of studies that attempt to rank the relative importance of different barriers, using either surveys or case study research. A key finding from both these sections is that *multiple* barriers to energy efficiency *coexist* and *reinforce* one another and that these barriers are *interdependent*. This and related conclusions are summarized in Section 6.

2 Methods and approach

This report is based upon earlier work by Sorrell *et al.* (2004), together with a review of 160 more recent studies of energy efficiency drawn from both the academic and 'grey' literature. Most of these studies were published after 2000 and therefore coincide with a period of intensifying global concern about climate change and rapidly rising emissions from industrializing economies such as China and India. The focus throughout is upon energy efficiency in the industrial sector, although some of the studies also include the public and commercial sectors. The report includes quantitative summaries of the results of these studies, together with more detailed examination of those studies which evaluate the relative importance of barriers. Full details of the studies reviewed are contained in an Access database which is available on request. This section provides some relevant definitions and summarizes the approach taken.

2.1 Key definitions

Energy efficiency

The term *energy efficiency* is widely used but not always well understood. It may be defined as the ratio of useful outputs to energy inputs for a system, where the latter may be an individual energy conversion device (e.g., a boiler), a building, an industrial process, a firm, a sector or an entire economy. In all cases, the measure of energy efficiency will depend upon how 'useful' is defined and how inputs and outputs are measured (Patterson, 1996). The options include:

Thermodynamic measures: where the outputs are defined in terms of either heat content or the capacity to perform useful work;

Physical measures: where the outputs are defined in physical terms, such as vehicle kilometres or tonnes of steel; or

Economic measures: where the outputs (and sometimes also the inputs) are defined in economic terms, such as value-added or GDP.

When outputs are measured in thermodynamic or physical terms, the term energy efficiency tends to be used, but when outputs are measured in economic terms it is more common to use the term ‘energy productivity’. The inverse of both measures is termed ‘energy intensity’. The choice of measures for inputs and outputs, the appropriate system boundaries and the timeframe under consideration can vary widely. However, physical and economic measures of energy efficiency tend to be influenced by a greater range of variables than thermodynamic measures, as do measures appropriate to wider system boundaries.

Economists are primarily interested in energy efficiency improvements that are consistent with the best use of all economic resources. These are conventionally divided into two categories: those that are associated with improvements in overall, or ‘total factor’ productivity (‘technical change’), and those that are not (‘substitution’). The latter is assumed to be induced by changes in the price of energy relative to other inputs. The consequences of technical change are of particular interest, since this contributes to the growth in economic output. However, distinguishing empirically between these two categories can be challenging, not least because changes in relative prices also induce technical change.

End uses

Energy consumption in the industrial sector is commonly classified as either *process* or *generic*. The former refers to energy used directly in the production process, whereas the latter refers to energy used for non-core applications such as heating, ventilation and air conditioning (HVAC), lighting and information technology. However, the boundary between these two categories is not always clear.

Process applications dominate overall industrial energy consumption and include compressed air, pumping, and fan systems (referred to collectively as motor systems), steam systems and high- and low-temperature process heat (Table 2.1). The main high-temperature process uses of energy are coke ovens, blast furnaces and other furnaces and kilns, while low-temperature process uses include process heating and distillation in the chemicals sector; baking and separation processes in the food and drink sector; pressing and drying processes in paper manufacture; and washing, scouring, dyeing and drying in textiles (DTI, 2002). Motor systems are used for pumping, fans, machinery drives, compressors (for both compressed air supply and for refrigeration) and conveyors, with refrigeration being especially important in the food and drink sector.

Different industrial sectors vary widely in their energy intensity, fuel mix and split between different end uses (Table 2.1 and Table 2.2) give illustrative data for the UK). High-temperature process heat is concentrated in the iron and steel, non-ferrous metal, bricks, cement, glass and ceramic sectors. Low-temperature process heat is the largest end use in food, drink and tobacco; while space heating and lighting are dominant in the engineering sector.

Table 2.1 UK industrial energy consumption by end use (1999)

Category	*Share of total*
Low temperature process heat	30%
High-temperature process heat	25%
Drying and separation	11%
Space heating	10%
Motor systems	8%
Other	16%

Table 2.2 UK industrial energy consumption by sector (2001)

Category	*Share of total*
Chemicals	22%
Food, drink and tobacco	12%
Iron and steel	10%
Mineral products	7%
Paper, print and publishing	6%
Mechanical engineering	5%
Vehicles	5%
Other industry	33%

Source: (DTI, 2002)

Barriers to energy efficiency

Following Sorrell *et al* (2004), a *barrier* to energy efficiency is defined here as "a postulated mechanism that inhibits a decision or behaviour that appears to be both energy efficient and economically efficient."

Although a widely used concept, barriers to energy efficiency are classified in multiple and overlapping ways in the literature which makes the comparison of different studies extremely problematic.

There are numerous lenses through which to examine potential barriers to energy efficiency. While most studies use economic concepts (including orthodox, transaction cost and behavioural economics), the concept of barriers can also be approached from the perspective of social psychology (Palmer, 2009) on organizational theory (Montalvo, 2008; Sorrell, 2000c). Some authors (e.g., Foxon, 2003) favor a systems perspective, whereby barriers and ways to overcome them are addressed at the macro-level. Such system-level barriers include carbon lock-in, dominant design, network effects, and path dependent technological trajectories. An *economics* based framework is used here as, first, the majority of literature reviewed uses this approach; and second, the primary focus of the UNIDO report is the profitability of energy efficiency investments.

The taxonomy used in this report is summarized in Table 2.3 and discussed in detail in Section 3. The taxonomy is based upon categories that are widely used within the energy efficiency literature, although the description and evaluation of these barriers in Section 3 draws upon more formal ideas, such as asymmetric information. The taxonomy covers most of the factors that are commonly claimed to inhibit investment in energy efficiency and although different studies may classify barriers in different ways; these can frequently be reinterpreted in terms of the categories in Table 2.3.

However, some studies highlight additional factors which are not included in Table 2.3 –such as the absence of government support for energy efficiency. Many of these do not qualify as barriers as defined above since they do not explain why a technology that is both energy and economically efficient has not been adopted. However, they frequently highlight important *contextual* factors which help explain why other barriers to energy efficiency have not been overcome (e.g., information deficits) and why the energy intensity of an industrial sector in one country is much greater than the corresponding sector in another. This applies in particular to the differing conditions within developed and developing countries.

Each of the barriers may be considered a hypothesis that potentially explains the neglect of energy efficiency within organizational decisions. But as discussed in Section 3, each of these barriers may have a number of contributory mechanisms and several of these mechanisms can coexist in different situations.

Table 2.3 A taxonomy of barriers to energy efficiency

Barrier	*Claim*
Risk	The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because energy efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons.
Imperfect information	Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market.
Hidden costs	Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information.
Access to capital	If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.
Split incentives	Energy efficiency opportunities are likely to be foregone if actors cannot appropriate the benefits of the investment. For example, if individual departments within an organization are not accountable for their energy use they will have no incentive to improve energy efficiency.
Bounded rationality	Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentives.

Other definitions

Other definitions relevant to the subject of this report are as follows:

Small and Medium Enterprises (SMEs) are defined as any enterprise with less than 250 employees (European Commission 2005).

Industrialised' nations are defined as high income members of the Organization for Economic Cooperation and Development (OECD). This includes Japan, Korea, the United States, Canada, Australia and New Zealand and 21 European countries. Three low income OECD members, Poland, Turkey and Mexico are excluded from this definition.

Emerging economies are defined as Brazil, Russia, India, Mexico, China and South Korea. These are sometimes referred to as middle income countries or the BRIC group of countries.[1]

Industrial sectors are commonly categorised as either energy-intensive or non energy-intensive on the basis (usually) of the percentage of input costs accounted for by energy. However, there is no standard definition and the categorisation varies from one study to another. As far as possible, this report uses the categorisation summarized in Table 2.4.

Table 2.4 Energy-intensive versus non-intensive sectors

Energy-intensive	*Non-intensive*
Cement,	Baking,
Automotive,	Food & Drink,
Paper & Pulp,	Glass,
Aerospace,	ICT,
Shipping,	Agriculture,
Chemicals,	Commercial,
Petrochemical,	Textiles,
Pharmaceuticals,	Wood manufacture
Refineries,	
Metals,	
Construction	

2.2 Scope and data collection

In compiling this report, we have reviewed a total of 65 academic studies and 95 studies from the 'grey' literature. This sample is substantial and representative, but is not intended to be comprehensive. Academic studies were selected via keyword search, which directed attention predominantly to specialist journals, including: *Energy Policy*, *Energy for Sustainable Development*, *Energy*, *Energy Economics*, *Journal of Cleaner Production*, *Resource and Energy Economics*, *Applied Energy*, as well as relevant academic books. The sources for the grey literature search reflect the recommendations of experts in the field and include: the European Council for an Energy Efficient Economy (ECEEE), the American Council for an Energy Efficient Economy (ACEEE), the Lawrence Berkeley National Labs (LBNL), the US Department of Energy (USDOE), the US Environmental Protection Agency (USEPA), the Organization for Economic Cooperation and Development (OECD),

[1] The term Brazil, Russia, India, Mexico and China (BRICs), stem from a 2001 and later 2003 Goldman Sachs report where these four countries were singled out in forecast scenarios to account for the majority of global GDP, economic growth and investment opportunities by 2050. In a 2005 Goldman Sachs paper, Mexico was also projected to have rates similar to the rest of these countries (O'Neill et al. 2005: 4), leading to the term BRIMCs. (This was further updated to include South Korea – BRIMCK in 2007) (O'Neill 2007);

the International Energy Agency (IEA), the Asia-Pacific Partnership (APP), the UK Carbon Trust and United Nations Industrial Development Organization (UNIDO). Inevitably, many more grey studies could be added, notably those produced primarily for audiences within particular industrial sectors. Our sample includes a group of reports relating to the *cement* industry as an illustration of the depth of information available at the sector level. Cement was chosen as an energy-intensive sector with a developed set of negotiated agreements and initiatives for energy efficiency monitoring and reporting.

The majority of grey studies (67 percent of n=95) and half of the academic studies (33 percent of n=66) relate to industrialized countries. The remainder relate to either developing countries, both developed and developing countries, or discuss general trends without reference to particular regions (for example, focusing on technology rather than context). To facilitate analysis, the key features and findings of these studies have been summarized within an Access database (available on request). The studies were categorized according to country/region, industrial sector(s) covered, size of firm (large or SME) and ownership (public versus private). The main findings of each study were briefly summarized, including those relevant to barriers to energy efficiency.

The 160 studies were grouped into five categories, as illustrated in Table 2.5. The studies ranged from technology-focused estimates of the benefits of selected energy efficiency technologies through to empirical 'in use' case studies, best practice recommendations, and policy recommendations and evaluation. Some studies were classified under more than one category since they met more than one of the descriptions indicated in Table 2.5.

Table 2.5 Type of study

Category	*Description*
Technological proposal	Provides quantified estimates of the energy-saving benefits of adopting particular technologies or processes.
Market scoping study	Collates descriptive and/or quantitative data on the existing use of technologies, processes and energy in particular sectors and/or regions. May in some cases provide estimates of potential energy savings through adoption of energy efficient technologies.
Regional case studies	Analyses the implementation of a technology or process, or its potential for energy efficiency, in a particular country or region.
Best practice of sector or firm	Recommends best practice drawn from empirical research of firms in a particular sector
Policy proposal or evaluation	Recommends policy options and/or evaluates impact of existing policy on energy efficiency.

Most of the analysis in this report is based upon two subsets of the data:

Empirical studies: 64 of the studies (40 percent of the total) were classified as 'empirical' in that they included primary data gathered directly from interviews and surveys or from the meta-analysis of other studies. It was this subset of studies that provided information on barriers to energy efficiency, although the nature, amount and quality of this information varied widely from one study to another. The barriers to energy efficiency identified and discussed in these studies were categorised as far as possible according to the taxonomy indicated in Table 2.3. This necessarily involved some judgment, since most of the studies did not use the same taxonomy as in Table 2.3. For each of these studies, we highlighted the three barriers that appeared to be the 'most prominent'. This was an impressionistic exercise, since the majority of studies did not indicate the relative importance of different barriers. This imprecision should be borne in mind when interpreting the quantitative results in Section 4.

Detailed studies: Seven of the studies were especially useful in that they attempted to identify the relative importance of different barriers to energy efficiency. This was achieved either through the econometric analysis of survey data (e.g., Schleich, 2009) or (more usually) from the less formal analysis of interview data (e.g., Hasanbeigi, et al., 2009). The results of these studies are summarized and compared in Section 5.

In addition to recording the findings on barriers to energy efficiency, note was also made of broader *contextual factors*, such as policy environments, sector norms and other constraints that, while operating outside the influence of individual firms, could nevertheless impede (or at least fail to encourage) their adoption of energy efficiency measures.

2.3 Overview of data collected

Our sample of studies suggests there has been a shift in research activity over time, from the relatively narrow quantification of potential savings linked to specific technologies towards more empirically-based studies to determine the circumstances in which these technologies are or are not implemented. Many of the empirically-based studies in our sample focus explicitly on barriers to adoption in both developed and developing country contexts (e.g., Coito, *et al.*, 2005; CSI, 2007; D'Antonio, *et al.*, 2005; Helgerud and Sandbakk, 2009; Koizumi, 2007; Motegi and Watson, 2005). Meanwhile, traditional sources of energy efficiency innovation, such as equipment vendors, university engineering departments and research institutes, highlight and quantify new sources of potential energy savings in a sector context (e.g., Dupont and Sapora, 2009; Lezsovits, 2009; NRC, 2006).

Table 2.6 and Figure 2.1 provide a breakdown of the sample by study type (see Table 2.5) and industrial sector. Many of the studies span more than one of the categories identified in Table 2.5, so the total row of Table 2.6 exceeds the number of studies. Studies providing best practice recommendations form the largest group, followed by regional case studies. These studies may mention barriers to adoption but the main objective is to present cumulative case study evidence for the benefits of particular technical options. Research in the form of technological proposals tends to focus on generic benefits rather than examining the practical implementation issues in specific sectors. Policy recommendations and evaluation tend to focus on broad areas of 'industry' and 'manufacturing', rather than specific sectors.

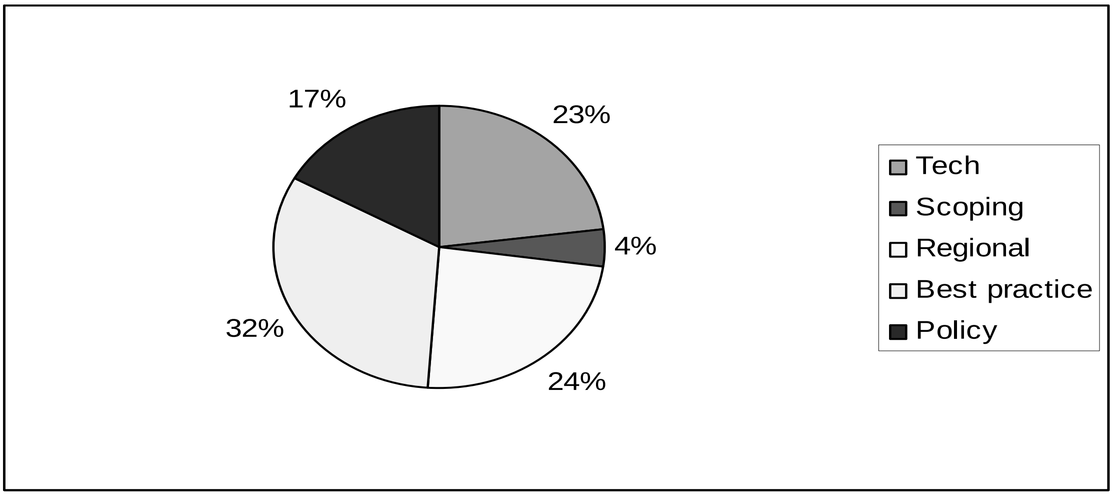
The categorization of studies by sector in Table 2.6 is non-exclusive. For example, a study may examine the application of a cross-cutting technology in one or more energy-intensive sectors, or in industry generally. Similarly, a single study may be of more than one type – for example, a case study may focus on a sector in a particular country or region.

Table 2.6 Classification of studies by type and industrial sector (n=160)

Study type	*No of studies*	*Cross-cutting*	*Energy-intensive*[3]	*Non energy-intensive*	*General*[4]
Technological proposal	54	21	9	6	18
Market scoping study	10	1	2	4	3
Regional case studies	56	15	15	3	23
Best practice of sector or firm	75	13	25	14	23
Policy proposal or evaluation	40	9	2	4	25
Total studies[1]	235	59	53	31	92

[1]Total number of studies is >160 as each study (n=160) can be categorized by multiple study types
[2] Cross cutting technologies are those with generic applications in multiple sectors. Examples include motors, fans, compressors, heat recovery and insulation.
[4]'General refers to studies that address a range of sectors described generically as either 'industrial' or 'manufacturing'.

Figure 2.1 Prevalence of study type as percentage of total



3 A taxonomy of barriers to energy efficiency

This section describes the nature and operation of six different barriers to energy efficiency in some detail, using a taxonomy developed by Sorrell *et al.* (2004). Each of the barriers represents a potential answer to one or more of the following questions:

- Why do organizations impose very stringent investment criteria for projects to improve energy efficiency?
- Why do organizations neglect projects that appear to meet these criteria?
- Why do organizations neglect energy efficient and apparently cost-effective alternatives when making broader investment, operational, maintenance and purchasing decisions?

Section 3.1 introduces three different perspectives on barriers to energy efficiency, clarifies the distinction between barriers and market failures, introduces a taxonomy of six barriers to energy efficiency and makes some observations on how these may be identified. The subsequent sections discuss the nature, operation and consequences of each of these barriers in some detail. Section 3.8 summarizes some contextual issues that should also be taken into consideration, while Section 3.9 concludes.

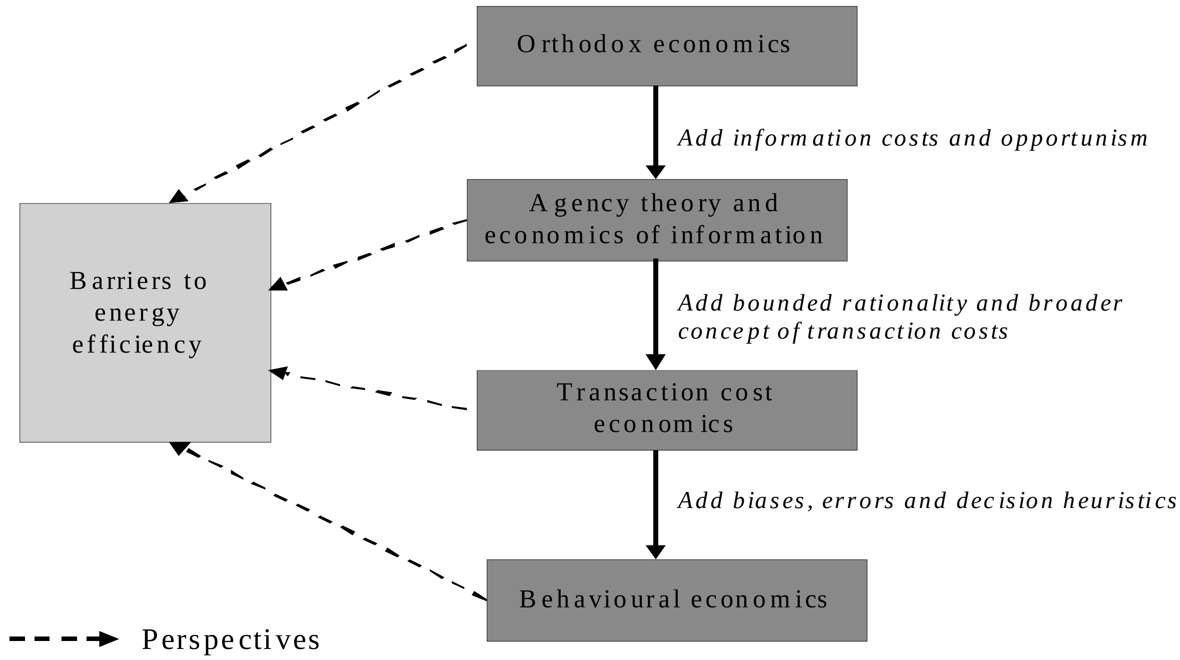
3.1 Perspectives on barriers

Underlying the debate on barriers to energy efficiency are competing assumptions about the nature of human rationality, the appropriate role of markets and the relative usefulness of different approaches to understanding economic behaviour. Scepticism about 'no regrets' opportunities derives largely from *orthodox economics*, which considers that policy intervention is only justified where the existence of market failures - such as asymmetric information - can clearly be demonstrated and where the benefits of intervention outweigh the costs. Orthodox economics relies upon highly formalised mathematical models and unrealistic assumptions about human decision-making. In contrast, *transaction cost economics* (TCE) assumes that individuals make satisfactory rather than optimal decisions and rely heavily on routines and rules of thumb (Furubotn and Richter, 1997; Simon, 1959; Williamson, 1985). *Behavioural* economics takes these arguments one stage further by arguing that decision-making is not just 'boundedly rational' but systematically biased and erroneous (Kahneman and Tversky, 2000; Piattelli-Palmarini, 1994). For example, individuals commonly exhibit 'loss-aversion' and a 'status quo bias' which can discourage them from undertaking cost-effective investments - such as the manager who declined to pursue a project with a 50-50 chance of either making $300k or losing $60k (Samuelson and Zeckhauser, 1988; Swalm, 1966; Thaler, 1991). Experimental tests suggest that such biases are universal, predictable and largely unaffected by either monetary incentives or learning (Kahneman and Tversky, 2000).

Studies of barriers to energy efficiency vary greatly in the extent to which they employ these ideas. Some discuss barriers with minimal reference to formal theory; some draw upon orthodox ideas but reject transaction cost and behavioural economics (Jaffe and Stavins, 1994),[2] and some make reference to concepts such as transaction costs, but do not develop their full implications (Sanstad and Howarth, 1994). The situation is further complicated by the blurring of boundaries between different approaches. Not only is there a great deal of overlap between these different perspectives, but the concepts used in the barriers debate frequently subsume more than one concept from these different traditions and refer to phenomena that can be explained by (and may well be caused by) more than one mechanism. The contribution of these different theoretical perspectives is illustrated in Figure 3.1.

[2] Although the founders of transaction cost economics (Oliver Williamson) and behavioural economics (Daniel Kahneman and Amos Tversky) have both been awarded the Nobel Prize.

Figure 3.1 **Perspectives on barriers to energy efficiency**



In determining the barriers to cost-effective energy efficiency improvements, an important consideration is whether these provide suitable grounds for policy intervention. For example, managers' informed assessment of local conditions may undermine the business case for investment, but the relevant costs may be 'hidden' in that they are not readily visible from outside the firm or sector. From the perspective of orthodox economics, these 'hidden costs' are not an appropriate focus for policy intervention since they do not constitute a market failure. Instead, the firm is assumed to be behaving rationally, given the risk-adjusted rate of return on an investment in the existing context of energy, capital and 'hidden' costs (which are assumed to be fixed). But from the perspective of transaction cost economics, such costs *may* be an appropriate focus of policy intervention since they could potentially be reduced by policy measures such as information programmes. From this perspective, hidden costs are not fixed, but depend instead upon the particular market, organizational and contractual arrangements. These in turn are amenable to change through organizational initiatives, public policy or a combination of the two.

Empirically identifying barriers to energy efficiency in different contexts is far from straightforward. The energy efficiency of a firm is influenced by multiple decisions taken at multiple levels, including strategic planning, budgeting, operations, maintenance, purchasing and so on. For example, the imposition of relatively high discount rates may provide a significant barrier to energy efficiency projects, but the underlying question is *why* such constraints are chosen. Hence, to accurately identify barriers to energy efficiency requires detailed insights into the firm's rules, procedures, incentives and routines. An additional challenge is that the researcher must analyse an historical phenomenon that hinges on decisions that were *not* taken. Detailed and time-consuming primary research is therefore required, involving either surveys of a large number of firms or case studies of a smaller number. The theoretical framework used to guide this research is of crucial importance and the existing literature if frequently weak, both in terms of its identification and description of relevant concepts (barriers) and in the methods used to identify the existence of those barriers (see Sorrell, *et al.* (2004) for a discussion). The result is a confused and methodologically weak set of studies from which relatively little consensus has emerged.

The six barriers used in this study are summarized in Table 3.1. The following sections discuss the nature, operation and consequences of each of these barriers in turn.

Table 3.1 A taxonomy of barriers to energy efficiency

Barrier	*Claim*
Risk	The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because such investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons.
Imperfect information	Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market.
Hidden costs	Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information.
Access to capital	If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.
Split incentives	Energy efficiency opportunities are likely to be foregone if actors cannot appropriate the benefits of the investment. For example, if individual departments within an organization are not accountable for their energy use they will have no incentive to improve energy efficiency.
Bounded rationality	Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect energy efficiency opportunities, even when given good information and appropriate incentives.

3.2 Risk

Both high discount rates for energy efficiency investments and the rejection of particular energy efficient technologies may represent a rational response to risk. For example, if there is doubt that a business will survive over the next three years, stringent investment criteria may be entirely appropriate. Risk may derive from a range of sources, including overall economic trends (e.g., inflation, interest rates), potential changes in government policy, trends in input and output markets (e.g., fuel and electricity prices), financing risk (e.g., the anticipated reaction of capital markets to increases in borrowing), and the technical risks associated with individual technologies (e.g., unreliability). These risks may be expected to vary with the individual country, sector, business and technology and to change over time. Furthermore, perceptions of risk by the relevant decision-makers may depart from those suggested by economic models (Tversky and Kahneman, 1991).

While risk is multidimensional, what matters for the barriers debate is the potential impact of real or perceived risks on energy efficiency investment, as opposed to other forms of investment. In other words, are there any reasons why energy efficiency investments or energy efficient alternatives should carry a higher risk than other forms of investment, and therefore be systematically overlooked?

The first possibility is that energy efficient technologies are subject to greater technical risks. For example, if technology is (or is perceived to be) unreliable, the risk of breakdowns and disruptions may outweigh any potential benefits from reduced energy costs. Such risks are particularly associated with new and unfamiliar technologies and these are commonly the subject of government funded demonstration programmes which aim to increase confidence and disseminate information and awareness among potential adopters. However, many of the technologies that are included in engineering-economic models and recommended in energy efficiency publications are well proven, reliable and widely used. These include, for example, energy efficient lighting, condensing boilers, thermal insulation, energy efficient motors, thermostatic radiator valves and lighting controls. In most applications the technical risk associated with these technologies appears to be small. Hence, unless perceptions diverge significantly from reality, technical risk seems unlikely to provide a reason for their rejection in the majority of cases.

A second possibility, suggested by Sutherland (1991), is that energy efficiency investments require higher hurdle rates because they are 'illiquid' and irreversible, with limited scope for diversifying risks. The comparison here is with investments in financial instruments, such as stocks and bonds, which are highly liquid since they can be easily bought and sold (Golove and Eto, 1996; Johnson, 1994). In comparison, energy efficiency investments are normally embedded within buildings and equipment, costly to remove and with limited scope for subsequent resale. Since they must generally be retained, regardless of their performance, they carry a greater risk than investment in other types of assets which suggests that the value of future benefits should be discounted more highly. But while this argument may account for the differing treatment of 'liquid' and 'illiquid' assets, it fails to account for the differing treatment of comparable assets. For example, why should cost saving energy efficiency investments be subject to more stringent investment criteria than investment in new production plant, when the latter is equally illiquid and irreversible? The scope of this argument may therefore be limited.

Hasset and Metcalf (1993) and Johnson (1994) present a similar argument to Sutherland, which is based on the concept of 'real options theory' (Dixit and Pindyck, 1994). They argue that the combination of uncertainty in the future course of energy prices, capital costs and technical change, coupled with the irreversibility of energy efficiency investments leads to an optimal rate of return which is higher than conventional investment models predict. One reason for this is that there is an opportunity cost in acting today, rather than delaying the decision and resolving some uncertainties. The possibility of delaying the decision represents an option, which has a value in proportion to the degree of uncertainty on investment returns. But since this option is no longer available once the investment has been made, the full cost of the investment should include the cost of foreclosing the option. This leads to a testable implication that required rates of return should be positively correlated with the degree of uncertainty of future returns (Metcalf, 1994).

Sanstad *et al* (1995) have criticised the Hasset and Metcalf model on three grounds. First, it fails by some distance to account for the observed discount rates for energy efficiency investments. They demonstrate that the 'option value multiplier' in Hasset and Metcalf's model falls off rapidly as the assumed discount rate increases, and has only a limited effect on the required rate of return (e.g., increasing from 15 percent to 17.4 percent). Second, the model fails to account for the potential *costs* of delaying energy efficiency investments (Howarth and Sanstad, 1995). For example, it is much more costly to retrofit heat recovery systems than to include them when a plant or building is designed. Since most decisions relevant to energy efficiency involve a choice between efficient and inefficient options within an investment that is being made for other purposes, the scope of the model is seriously circumscribed. Third, the model has the usual limitations of orthodox theory in that it assumes investors are fully informed about relevant alternatives and able to solve sophisticated optimisation problems. This compares poorly with models that take account of limitations on decision-making, and is inconsistent with empirical studies of energy demand behaviour.

Given these considerations, the argument that high discount rates can be considered a rational response to risk for most types of energy efficiency investment does not seem plausible. The quantitative predictions of the models fail on their own terms, quite apart from the implausibility of the behavioural assumptions and the limited range of investment decisions for which they seem applicable. However, business, regulatory or technical risk may be a relevant and important factor in some cases.

3.3 Imperfect information

The importance and policy implications of imperfect information are one of the central issues in the barriers debate. The primary claim is that, for a variety of reasons, individuals lack adequate information on either individual energy efficiency opportunities or on the energy performance of different technologies. This leads them to make sub-optimal decisions based on provisional and uncertain information, and consequently to under-invest in energy efficiency. Since imperfect and asymmetric information are central to the orthodox understanding of market failures, the existence of imperfect information is claimed to justify policy interventions to improve information such as energy labelling. Huntington *et al* (1994) argue that '…information problems taking different forms are the principal source of market failures that account for the "gap" in energy efficiency investments'.

Imperfect information in energy service markets

The information relevant to energy efficiency decisions may usefully be grouped into three categories: information on the level and pattern of current energy consumption and the comparison of this with relevant benchmarks; information on specific energy-saving opportunities, such as the retrofit of thermal insulation; and information on the energy consumption of new and refurbished buildings, process plant and purchased equipment, allowing choice between efficient and inefficient options.

The availability of information on current energy consumption will depend upon the information content of utility bills, the level of sub-metering, the availability of relevant benchmarks, the use of computerised information systems, the time devoted to analysing consumption information and so on. Most of these will be associated with investment, operational and staff costs which may best be understood as a particular category of transaction cost. These costs are of fundamental importance to the barriers debate and are discussed more fully in the next section.

The availability of information on energy-specific investment opportunities will depend upon two factors: the extent to which organizations have evaluated energy efficiency opportunities through measures such as energy audits; and the availability of information on the costs and performance of specific energy-saving technologies. The first of these involves costs for the organization (whether the audits are conducted in-house or by external consultants), and these may also be understood as a form of organizational transaction cost (see Table 3.3).

Information on specific energy efficient technologies should be available in the marketplace, but the cost, quality and accuracy of this information may vary widely between different technologies. To the extent that this information has the characteristics of a public good, there may be a case for publicly funded information programmes and demonstration schemes - especially for new and unfamiliar energy efficiency technologies.

The extent to which information is available on the energy consumption of new and refurbished buildings and purchased equipment will depend very much upon the characteristics of the relevant market. Energy efficiency is not a stand-alone product in these markets, but a secondary and often relatively unimportant feature of a wide range of goods and services (Golove and Eto, 1996). Energy services are delivered through a combination of energy commodities, building and transport infrastructures and energy conversion technologies, and the decisions made on the specification, design, purchase, installation, operation, repair and maintenance of a wide range of technologies will influence the overall energy efficiency performance (Golove and Eto, 1996). The informational problems associated with energy service markets will therefore be specific to individual technologies and services (e.g., motors, lights, buildings, pumps, appliances). If the required information is unavailable, of poor quality, overly complicated or unreliable, the market signals in favour of energy efficient products and services are likely to be relatively weak.

Asymmetric information in energy service markets

Asymmetric information exists where the supplier of a good or service holds relevant information, but is unable or unwilling to transfer this information to prospective buyers. The extent to which asymmetric information leads to market failure will depend upon the nature of the good or service. Economists commonly classify goods into three categories: search goods: where a consumer can determine characteristics with certainty prior to purchase; experience goods: where consumers can only determine characteristics after purchase; and credence goods: where it is difficult for consumers to determine quality even after they have begun consumption.

Energy service markets are likely to be characterised by asymmetric information between producer and purchaser and between market intermediaries at different stages along the supply chain. The importance of this will depend upon the variance in product quality (particularly in relation to energy efficiency), the frequency of purchase relative to changes in underlying characteristics and the ‘search costs’ entailed in obtaining relevant information. It is useful here to compare the relative importance of asymmetric information for the purchase of energy commodities such as gas and electricity, compared to the purchase of energy efficiency products or energy efficiency equipment which may allow the same level of energy service to be obtained at lower levels of energy consumption (Hewett, 1998). For example, the same level of thermal comfort may be obtained by using more fuel within an existing heating system, or by investing in loft insulation, cavity wall insulation, draught stripping and/or double glazed windows.

Energy commodities represent a simple, unchanging, easy to understand and homogenous product which is purchased from a small number of large, established and generally well trusted firms. Purchases are made regularly, market information is widely available and 'performance' is judged largely on price. Hence, energy commodities can be considered a *search good* with relatively low search costs.[3] In contrast, delivering the same service through energy efficiency investment requires the purchase of one or more complex, heterogeneous and unfamiliar goods from markets with multiple suppliers and intermediaries. Since the lifetime of such products is long (e.g., 15 years), the purchases are infrequent and the rate of technical change is rapid relative to the purchase interval (Hewett, 1998). For example, technologies such as condensing boilers, building energy management systems and electronic ballasts have improved enormously over the last ten years.

In contrast to energy commodities, energy efficiency may only be considered a search good when the energy consumption of a product is clearly and unambiguously labelled and when the performance in use is insensitive to installation, operation and maintenance conditions. But for many goods, the information on energy consumption may be missing, ambiguous or hidden, and the search costs will be relatively high. In the absence of standardised performance measures or rating schemes, it may be difficult to compare the performance of competing products. Even when rating schemes are available, the performance in use may depart significantly from the rated performance – for example when technologies are operated on part load or are inadequately maintained. Also, customers may have great difficulty in evaluating the performance claims of technology suppliers, or may be suspicious of these claims. In these circumstances, energy efficiency is better described as an *experience good*.

In practice the performance of technologies such as control systems, motors and variable speed drives may be very difficult to evaluate even after purchase. In most cases, the evaluation of energy performance would require low level electronic sub-metering, adjustment for variable factors such as occupancy and weather, and careful analysis of consumption patterns over time. If this is not done, the purchaser will lack feedback on the consequences of different purchase decisions, with the result that energy use will be relatively invisible (Hewett, 1998). For example, Kempton and Layne (1994) have compared the information value of the average household energy bill to that of receiving a single monthly bill from the supermarket for 'food'. Taken together, these features tend to make energy efficiency closer to a *credence good* and hence more subject to market failure. Thus, to the extent that energy supply and energy efficiency represent different means of delivering the same level of energy service, the latter is likely to be disadvantaged relative to the former. The result is likely to be over-consumption of energy and under-consumption of energy efficiency (Hewett, 1998).

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[3] In the UK, the liberalization of gas and electricity supply markets has increased competition and choice while the same time increasing search costs. This process has undoubtedly brought benefits to large users, but the benefits for household consumers are less clear (Waddams, 2003).

The choice between energy supply and energy efficiency is most relevant to energy-specific investment opportunities, such as thermal insulation. But in practice, a more common choice is between an energy efficient or inefficient product or service, when a decision is required anyway – for example, replacing an existing boiler which has come to the end of its life. What is relevant here is the availability of information on the energy performance of the product (and the consequent savings in operating costs) as compared to the availability of information on other attributes of the product, such as capital costs. This in turn will depend upon the relative importance of energy consumption as compared to the other services delivered by the product. For example, thermal efficiency may be expected to be an important and visible attribute of a boiler. But energy efficiency may be expected to be very much a secondary attribute of other products such as buildings, and is likely to be determined by wide range of design and operational factors, the net effect of which may be difficult to assess. In the absence of clearly specified and comparable performance information, energy efficiency considerations are likely to be easily outweighed by other more visible features. Hence, even if energy efficiency is valued by the consumer, the lack or cost of information may prevent this preference from being exercised: '….Faced with good information on capital costs and poor information on operating costs, consumers may rationally and systematically choose the low capital option' (Eyre, 1997).

Adverse selection in energy service markets

In some circumstances, asymmetric information in energy service markets may lead to the adverse selection of energy inefficient goods. Take housing as an example (Jaffe and Stavins, 1994). In a perfect market, the resale value of a house would reflect the discounted value of energy efficiency investments. But asymmetric information at the point of sale tends to prevent this. Buyers have difficulty in recognising the potential energy savings and rarely account for this when making a price offer. Estate agents have greater resources than buyers, but similarly neglect energy efficiency when valuing a house. Since the operating costs of a house affect the ability of a borrower to repay the mortgage, they should be reflected in mortgage qualifications. Again, they are not. In all cases, one party (e.g., the builder or the seller) may have the relevant information, but transaction costs impede the transfer of that information to the potential purchaser. The result may be to discourage house builders from constructing energy efficient houses, or to discourage homeowners from making energy efficiency improvements since they will not be able to capture the additional costs in the sale price.

The same processes are at work in a range of energy services markets. In some cases, producers may be unable to market desirable technologies since consumers are unable to observe their characteristics prior to sale (Howarth and Sanstad, 1995). In other cases, information asymmetries may create incentives for producers or suppliers to act opportunistically. For example, the energy efficiency of commercial buildings depends heavily on the detailed features of heating, ventilation and controls such as Building Energy Management Systems (BEMS). But in comparison to highly visible features such as outward form and aesthetics, the performance of building services equipment is extremely difficult for the customer to observe. Substitution of an inefficient or oversized piece of equipment in place of efficient equipment could be relatively easy since it would be hard to spot. The result may be inefficient products driving efficient products off the market – termed 'adverse selection' (Akerlof, 1970).

Summary

In summary, problems of imperfect information are likely to pervade energy service markets and could potentially explain a substantial proportion of the efficiency gap. First, the acquisition of information through measures such as metering and audits involves investment and transaction costs which may not be taken into account in engineering-economic models. Second, the search costs for energy efficient products are likely to be much greater than those for energy commodities, creating a systematic bias against energy efficiency. Third, energy efficiency has the characteristics of a credence good, which makes it particularly vulnerable to information market failure. And fourth, asymmetric information in energy service markets may sometimes lead to the adverse selection of energy inefficient goods.

The appropriate policy response to these market failures is contested. While information programmes appear to be the most obvious approach, minimum energy efficiency standards may be more effective in some instances. If information programmes are to be employed, both the manner in which information is presented and the credibility of the source are important.

The importance of information costs suggests that there is a considerable overlap between imperfect information and hidden costs. The next section clarifies these overlaps in more detail.

3.4 Hidden costs

Hidden costs represent the most important and influential explanation for the 'efficiency gap'. The claim is that engineering-economic studies fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with their use (Nichols, 1994). As a consequence, the studies tend to overestimate energy efficiency potential.

Components of hidden costs

In the energy economics literature, the term 'hidden costs' refers to any costs which are not conventionally included within engineering-economic models. Three possible sources of hidden costs are:

the general *overhead* costs of energy management; the costs which are *specific* to an individual investment in energy efficiency, or the choice of an energy-efficient option; and the potential loss of *utility* associated with energy efficient choices.

Table 3.2 identifies the possible components of these costs in more detail. Each of the cost categories may be both real and significant and each may partly account for the gap between real world investment behaviour and the predictions of engineering-economic models. But the different categories vary widely in their likely importance in particular instances, the extent to which they are specific to individual sites and technologies, the ease with which they can be quantified and incorporated into energy models, the extent to which they can be reduced by changes in organizational procedures and routines, and their relevance for public policy. It is tautologous to assert that hidden costs *must* be present if organizations are not adopting particular energy-efficient technologies. Instead, it is necessary to demonstrate what (if any) those costs are, why they are important, what is determining them and whether and how they could be reduced.

Table 3.2 Different types of hidden cost

Sub-category	*Examples*
General overhead costs of energy management	• costs of employing specialist people (e.g., energy manager) • costs of energy information systems (including: gathering of energy consumption data; maintaining sub metering systems; analysing data and correcting for influencing factors; identifying faults; etc.); • cost of energy auditing;
Costs involved in individual technology decisions	• cost of: i) identifying opportunities; ii) detailed investigation and design; iii) formal investment appraisal; • cost of formal procedures for seeking approval of capital expenditures; • cost of specification and tendering for capital works to manufacturers and contractors • additional staff costs for maintenance; • costs for replacement, early retirement, or retraining of staff; • cost of disruptions and inconvenience;
Loss of utility associated with energy efficient choices	• problems with safety, noise, working conditions, service quality etc. (e.g., lighting levels). • extra maintenance, lower reliability,

Some hidden costs could be considered part of the *production* cost of energy efficiency and could in principle be included in engineering-economic models (Ostertag, 2003). Examples include design fees for large items of plant, the civil engineering costs associated with installing a CHP unit, the costs of re-routing pipework, the reinforcement costs associated with connecting a CHP unit to the grid, the costs of rebuilding a flue after a condensing boiler has been installed, the cost of new light fittings to accommodate compact fluorescents, and the cost of production interruptions during equipment installation. These costs are site-specific and difficult to estimate, so they may be easily overlooked. But they represent real costs and organizations can be expected to take them into account in when appraising investment opportunities.

A second group of costs relates to the inferior performance of energy efficient technologies along a number of dimensions other than energy consumption. For example: an energy-efficient production process may lead to increased noise; the installation of cavity wall insulation in an old building may encourage damp; a variable speed drive may require extra maintenance or require new skills and tools; an energy-efficient motor may be less reliable; the lighting quality from compact fluorescents may be less desirable than that from incandescent bulbs; and so on (Golove and Eto, 1996). While these considerations clearly apply to energy-specific investment opportunities, they are likely to be even more important for investments where energy efficiency is only one of a number of attributes under consideration. Again, in principle these costs could be incorporated within engineering-economic models, but this may be difficult to achieve in practice.

A third group of costs corresponds to the search costs identified in the economics of information. These include the cost of identifying suppliers and obtaining information on price, quality and terms of trade. As argued above, these costs are strongly influenced by the characteristics of particular energy service markets and by the nature of energy efficiency as a good. They are determined in part by factors outside the control of the adopting organization, such as the existence or otherwise of standardized labelling schemes, and in part by organizational procedures for information gathering, specification, purchasing and procurement. Search costs are therefore influenced by a mix of factors both internal and external to the organization, and public policy should have greater scope for influencing the latter than the former.

Search costs represent a subset of the broader category of transaction costs. These include all the organizational costs associated with establishing and maintaining an energy management scheme, investing in specific energy saving technologies, and implementing specific energy efficient options within broader investment programmes (e.g., choosing energy efficient motors in preference to standard motors). In contrast to the production costs and loss of utility discussed above, transaction costs depend closely upon organizational and contractual structures, procedures, incentives and routines. This makes them much more difficult to incorporate within models which represent costs purely in relation to individual technologies.

To summarize the above, Table 3.3 provides a theoretical perspective on the components of hidden costs which complements the empirical perspective provided by Table 3.2. This divides hidden costs into four categories: production costs; loss of utility; market transaction costs; and organizational transaction costs. The first two of these categories may be considered as real and unavoidable costs which have no implications for public policy, while the last two categories are contingent upon the relevant market, contractual and organizational structures and hence may in some circumstances be lowered through public or private actions. Identifying the size and determinants of transaction costs is likely to be difficult, but four important features of these costs are as follows (Ostertag, 2003):

Table 3.3 Theoretical perspectives on the components of hidden costs

Sub-category	***Influenced by***	***Examples***
Hidden production costs	• Attributes of technology • Site-specific factors	Civil engineering costs, grid reinforcement costs, production interruptions
Loss of utility	• Attributes of technology • Site-specific factors	Increased noise, reduced service quality
Market transaction costs	• Features of primary and secondary markets for information. • Organizational procedures for external transactions	Search costs for gathering and assimilating information regarding product quality; cost of specification and tendering; bargaining and negotiation costs; legal advice; etc.
Organizational transaction costs	• Organizational procedures for internal transactions	Monitoring and control costs; decision-making costs; costs of establishing, maintaining and running energy information systems; etc.

Transaction costs need not increase in proportion to the volume of the transaction. So for example, the transaction costs associated with identifying and purchasing an energy-efficient motor will form a declining proportion of total life cycle costs as the size of the motor increases. Transaction costs are likely to be incurred for both energy efficient and inefficient choices. So if a replacement motor is required, there will be transaction costs for purchasing both energy efficient and inefficient models, and what matters is the difference between the two. Transaction costs may only accrue once when organizational routines are changed, such as when a shift is made from purchasing standard to high frequency fluorescent lighting. So comparing an exceptional situation with an established organizational routine may overstate the costs involved. Transaction costs may decrease over time as a result of learning effects as knowledge becomes embedded within individual and organizational routines. So they should not be treated as a fixed and unchanging.

Quantifying hidden costs

Estimates of hidden costs are rare in the literature. One example is a study by Hein and Blok (1994) which estimated the staff costs associated with collecting information, making decisions and monitoring the performance of different types of energy efficiency investments within large, energy-intensive firms. The transaction costs were dominated by search costs and typically formed between 3 percent and 8 percent of the total investment cost. This suggests that transaction costs were relatively small for this type of organization, but they could be much more important for small scale investments or for smaller, less energy-intensive firms. Transaction costs are therefore relative to the technical and organizational context.

For organizations, one of the most important sources of hidden costs is likely to be the overhead costs of energy management. These do not seem to have been subject to serious academic study, but are frequently cited by industry as the biggest obstacle to cost-effective investment. For example, negotiated agreements between government and industry in the UK require the implementation of energy efficiency projects with paybacks as short as three years. The primary reason given by UK industry for the use of these strict investment criteria is the management time required to identify and implement such projects (ETSU, 2001). These claims should be treated with suspicion, given the information asymmetry between government and industry and the incentive for industry to exaggerate the importance of hidden costs in order to reduce the stringency of the negotiated agreements. But they demonstrate that management time is a predominant concern and that it is accepted by the UK government as an adequate explanation of the efficiency gap.

Some simple calculations can demonstrate the potential importance of overhead costs for a typical organization. Best practice literature in the UK recommends that a sum equivalent to 5 percent of an organization's annual energy expenditure be reserved for dedicated energy efficiency investment. For a site with annual energy costs of £1 million, this would equal £ 50k which is comparable to the annual salary costs for a full-time energy manager. In this context, stringent payback criteria for such investment projects may be justified as a means to recover the salary overheads – for example, by transforming a five year payback into a three year payback. Furthermore, organizations with a small energy bill would only be able to devote a fraction of staff time to energy efficiency and would be unlikely to develop the relevant energy management skills. However, much of energy management could be seen as an essential function necessary for the functioning of the institution and the comfort of employees – for example, overseeing maintenance, running building energy management systems and negotiating with energy suppliers. Other tasks such as internal reporting, maintaining and upgrading information systems, training, marketing, and awareness raising are unlikely to produce direct savings, but are essential to creating a climate that is supportive of attempts to improve energy efficiency. As a result, it appears unreasonable to require *all* the salary overheads to be recovered solely from the returns on individual energy efficiency projects. At the same time, it appears equally unreasonable for *none* of the salary overheads to be recovered from such projects.

Summary

In sum, the majority of energy efficiency investments are likely to be associated with some form of hidden cost, and these costs could potentially explain a portion of the efficiency gap. A proportion of these costs may be considered part of the production cost of energy efficiency and hence provide no rationale for policy intervention. But a proportion may be understood as market or organizational transaction costs and hence could potentially be reduced through organizational changes or public policy. Hence, while the assertion that hidden costs can explain the entire efficiency gap is merely tautologous, the assertion that hidden costs are unimportant is equally likely to be wrong. The truth should lie somewhere between the two, but the relative importance of different categories of cost is likely to vary between individual technologies and organizations. It appears likely, however, that the salary overheads associated with energy management will be a major obstacle for many organizations, and especially for those with relatively small energy bills.

3.5 Access to capital

A commonly cited barrier within the energy efficiency literature is the lack of access to capital (Hirst and Brown, 1990). This may be particularly applicable to smaller companies who have less ability to offer collateral and may only be able to borrow at high interest rates. This could prevent energy efficiency projects with a high rate of return from being undertaken. The orthodox response to this argument is that while inability to access capital may constitute a barrier, it need not imply a failure in capital markets. Capital should be allocated to projects with the highest risk adjusted rate of return, smaller companies may be high risk borrowers (Sutherland, 1996). An alternative view is that the transaction costs entailed in investigating the credit worthiness of such companies are sufficiently high to diminish the economic viability of loans (Golove and Eto, 1996).

The ‘access to capital’ problem has two components: insufficient capital through internal funds, and potential difficulty in raising additional funds through borrowing or share issues; and neglect of energy efficiency within internal capital budgeting procedures, combined with other organizational rules such as strict requirements on payback periods. Both of these are the subject of a voluminous theoretical and empirical literature (Myers, 2001; Stein, 2001). Some key points are discussed below.

Accessing external sources of capital

Within private sector firms, restrictions on capital are often self-imposed. Here firms appear reluctant to borrow money to finance low risk energy efficiency projects with rates of return that significantly exceed their weighted average cost of capital (WACC).[4] In some cases, this reluctance appears to result from the perceived risk of increasing the ratio of loan finance to equity finance – termed *gearing* (Ross, 1986). Loan finance should be valuable up to a point, since it tends to be cheaper than equity – historically, the expected returns from equities are higher than those from loan stocks, and loans tend to have a more favourable tax treatment. But loan finance carries risk in that it imposes obligations to meet annual interest charges and to repay the principal. In contrast to share dividends, these are fixed obligations and are not at the firm's discretion. High levels of gearing may therefore expose the firm to the risk that it will not be able to meet its payment obligations should it experience a downturn in business.

With loan finance, the lenders have the legal right to enforce payment of the interest and repayment of the capital, using the assets of the company as security. In contrast, ordinary shareholders do not have the right to enforce the payment of a dividend. This situation means that high levels of gearing may expose the shareholders to greater risk as all the firm's profits could be eaten up in the repayment of lenders. As result, shareholders may demand higher returns as compensation. Furthermore, high levels of gearing may also expose the *lenders* to greater risk, since the asset value may be insufficient to pay off the outstanding loans should the firm go out of business. Hence, lenders may also demand higher interest payments on loans as the level of gearing increases. The level of risk will depend in part upon the resale value of the assets and also upon the proportion of total costs within the firm which are fixed – termed *operating gearing*. The risk of bankruptcy is particularly high for firms which are highly geared in both operating and capital terms, since relatively small fluctuations in the level of sales can have a dramatic effect on profits (Mclaney, 1994). The net result is that, while loan finance may reduce a firm's cost of capital at low levels of gearing, it may increase risk and raise a firm's cost of capital at high levels of gearing. Management may therefore restrict the level of gearing to a level they feel comfortable with.

This traditional view of an 'optimal' level of gearing was challenged by Modigliani and Miller (1958), who showed that, given a set of assumptions about the operation of the capital market, the advantages of cheaper loan finance should be exactly offset by the increasing cost of equity. As a result, the WACC should be independent of the level of gearing and should depend solely upon business risk and future cash flows. But this model effectively assumes that the transaction costs within capital markets are zero (Frubotn and Richter, 1997). Also, this theoretical result is not supported by the empirical evidence, which shows a reluctance to increase gearing beyond a particular level (Myers, 2001).

4 This is calculated from the relative proportions of loan stock and equity for the individual company, and their respective market values (Mclaney, 2000, p. 249).

Other perspectives on the use of capital markets emphasise information asymmetry and agency problems. For example, increased gearing may be in the interest of shareholders if it lowers the cost of capital, but may not be desirable from the perspective of company directors because it imposes a discipline which they may prefer to avoid. This could dissuade directors from using external funds to finance cost-effective investments. Similarly, Myers and Majluf (1984) emphasise how reliance upon external finance may be interpreted by investors as a signal that the existing assets are overvalued. It is commonly observed that an attempt to raise additional equity finance or to increase the level of gearing can weaken a firm's financial rating and drive down share and bond prices. Since debt imposes both greater risk on the firm and greater discipline upon managers, it should have a smaller impact than share issues. But in all cases, the cost of obtaining additional capital may exceed the average cost of the existing debt/equity mix (Ross, 1986). The prediction, therefore, is that firms will: a) prefer internal to external finance; b) prefer debt finance to equity; and c) avoid high levels of gearing (Myers, 2001).

Since most energy-specific investment opportunities involve relatively small amounts of capital, they should have very little impact on the level of gearing for the firm as a whole (particularly for larger companies). But since borrowing requirements and 'financing risk' are likely to be assessed for the firm as a whole, and not for individual investments, the effect may be to restrict the overall capital budget for investment, including that for energy efficiency. This effect may be exacerbated by internal capital budgeting procedures which give a lower priority to discretionary cost saving investments (see below), with the result that the dedicated energy efficiency budget is reduced. There are analogous problems with energy efficient options within broader capital investments, such as new buildings. These are typically subject to tight constraints on the capital budget combined with a strong incentive to keep the project within budget. Given the transaction costs associated with seeking (small) additional increments of funding, the budget for energy efficient options (with higher capital costs but lower operating costs) may be squeezed.

In sum, the conventional view that firms should invest in all projects which have a rate of return exceeding the WACC appears over simplistic. There may be very good reasons for not taking on additional debt or raising additional equity, but these require judgements about business risk and the response of the financial market to any increase in gearing. This makes it difficult to assess whether the behaviour of any individual firm is rational, or whether it reflects a failure on the part of management.

Accessing internal sources of capital

Two observations are commonly made in respect of the organizational treatment of dedicated energy efficiency investments. First, such investments tend to be classified as discretionary business maintenance projects, which are given a lower priority than either essential business maintenance projects, such as replacing a failed pump, or strategic business development investments, such as a new manufacturing plant (Department of Energy, 1983). Second, such projects tend to be evaluated using payback rates rather than discounted cash flow analysis, with the required rates of return exceeding those for business development projects (Train, 1985).

A number of hypotheses have been proposed to explain this behaviour, but a common theme is asymmetric information within internal agency relationships, such as those between central and divisional management. The agent (e.g., the divisional manager) is closest to a project and is likely to know most about its prospects, but at the same time may have an incentive to misrepresent this information. The principal (e.g., central management) cannot observe either the true quality of decision-making or the true profitability of the project. Principals will be unfamiliar with the specific local conditions in which the agent makes her decisions and there will be transaction costs entailed in transmitting the relevant information. This creates the risk that profits will be dissipated into 'managerial slack' – defined as the excess of resources over the minimum required for the task (DeCanio, 1993). One method of reducing this slack is to set the rate of return for investment projects to be substantially above the cost of capital to ensure that only highly profitable investments are undertaken (Antle and Eppen, 1985). Furthermore, the hurdle rate may be expected to be higher for small investments, since the transaction costs of determining the profitability of such investments are likely to represent a greater portion of the expected savings. Energy efficiency investments frequently fall into this category of small, cost saving investments.

A second explanation could be the strategic priorities of top management. DeCanio (1994) suggests that managers are primarily concerned with ensuring the long-term survival of their organization, which involves focusing upon dynamic factors such as the introduction of new products and the development of new production facilities. Given severe constraints on time and attention (i.e. bounded rationality), the small reductions in costs available from energy efficiency investments could easily be downgraded and overlooked. This is despite the fact that such investments have frequently been shown to have a higher rate of return than large projects which receive more management attention (Ross, 1986). This focus is unlikely to change until energy becomes more of a strategic issue, perhaps through energy prices internalising the external cost of carbon emissions.

The bias towards strict investment criteria may be exacerbated by the incentives on individual managers, including the asymmetry between the risks and rewards of energy efficiency projects. The failure of a project in which an individual had invested considerable effort could be very detrimental to that person's career, while the success of a comparable project could provide a much smaller career boost (DeCanio, 1994). Similarly, managerial advancement may best be achieved through large, strategic projects, while the compensation and prestige for energy management activities may be limited. Hence, as with accessing external sources of capital, there may be both good reasons and strong incentives for imposing strict investment criteria or restricting capital budgets for energy efficiency investments.

3.6 Split incentives

Split incentives were discussed earlier and were argued to result from asymmetric information and the transaction costs of developing shared savings contracts. While this barrier is most commonly cited in relation to rental housing, it is of much wider applicability.

Landlord-tenant problems may arise in the industrial, public and commercial sectors through the leasing of buildings and office space. For example, in the UK only 10 percent of commercial property is occupied by the freeholder and 70 percent is multi-tenanted. Much of the stock is owned by institutional investors who treat the property purely as an asset, while management is outsourced to property consultants who pay little attention to energy efficiency. Tenants may have little motivation to improve the performance of an asset they do not own, particularly if they have a short term lease, while owners will be happy to pass on the energy costs to their tenants. In many cases, tenants will simply pay a fixed pro-rata share of the building's energy bill, which means the savings generated by investment or behavioural changes by one tenant would accrue to all the other tenants as well, thereby diluting the incentive. The problem could be overcome through low level sub-metering, but this may be costly and it appears to be relatively rare. The landlord-tenant hypothesis suggests an obvious empirical test – whether the energy performance of leased buildings is significantly poorer than other buildings – but there appears to be little research on this topic, and the available evidence is limited.

Within organizations, the bias towards projects with short term paybacks may also result from split incentives. It is often the case that managers remain in their post for relatively short periods of time (DeCanio, 1993). In large companies, there may even be a policy of job rotation. But a manager who is in a post for only two or three years has no incentive to initiate investments that have a longer payback period. The incentive structure may therefore be skewed towards projects with rapid returns – although these may prove inferior to others if a full discounted cash flow analysis were performed. As with landlords and tenants, problems of information and transaction costs may prevent the incentive structure from being modified. Statman and Sepe (1984) point to a related issue in that, even without job rotation, management incentive structures are typically biased towards short term performance.

In larger organizations, departmental accountability for energy costs may be an important issue. If individual departments are accountable for their own energy costs, they could directly benefit from any savings from investment projects or housekeeping measures. But if cost savings are recouped elsewhere, this incentive is diluted. To introduce such accountability, it would be necessary to sub-meter and bill individual cost centres for their energy use – which would be associated with investment, staff and operational costs. The resulting incentives will be proportional to the importance of energy costs to the individual department and would only be effective if the department had the capacity to identify and initiate energy efficiency improvements and the budget to fund them. An alternative approach would be to place accountability for energy costs with the energy management staff, perhaps with individual posts made self-funding from the savings from energy efficiency improvements. The difficulty here is in identifying these savings and in adjusting for other sources of demand growth which are beyond the control of energy management staff. While energy management staff should have the capacity and skill to initiate energy efficiency improvements, they may lack local knowledge of individual efficiency opportunities. The appropriate solution will depend very much on the size and structure of the organization and complex issues of accountability may arise.

Very similar issues arise in equipment purchasing. The purchaser may have a strong incentive to minimise capital costs, but may not be accountable for running costs. Many items of equipment may be specified and procured by individuals who lack the knowledge, information and incentives to minimise operating costs, while constraints on staff time my inhibit the involvement of energy management staff. In a similar manner, maintenance staff may have a strong incentive to minimise capital costs and/or to get failed equipment working again as soon as possible, but may have no incentive to minimise running costs. This type of issue may also arise with building users, operators of process equipment and designers and sub-contractors within construction projects. In each case, the responsibility for capital costs may not match the responsibility for operating costs, while the transaction costs of reducing the problem may outweigh the potential savings to be achieved.

3.7 Bounded rationality

Several of the barriers discussed above (e.g., risk) would still apply if actors were gifted with the perfect rationality assumed in orthodox theory. In other cases (e.g., hidden costs), bounded rationality may be considered partly responsible for the barrier, since it contributes to the existence of transaction costs. But bounded rationality may also be classified as a barrier itself, since it contributes to decisions which depart from those predicted by orthodox models. This may occur even when actors have adequate motivation, incentives and information and when other barriers to energy efficiency are absent. For example, Eyre has argued that: '...There is a market failure to the extent that consumers do not attempt to maximise their utility or producers their profits.' (Eyre, 1997). The benchmark for this judgement is the 'optimising' rationality assumed in orthodox theory. As Sanstad and Howarth note: '...individuals and firms do not always behave according to the logic of economic rationality *but they should*. They need policies to help them do it.' (Sanstad and Howarth, 1994). The findings of behavioural economics may allow these departures from full rationality to be predicted and may also inform the design of policy interventions.

A primary consequence of bounded rationality is that constraints on time, attention, resources and the ability to process information lead to optimising analyses being replaced by imprecise routines and rules of thumb. In organizations, this could mean focusing on core activities, such as the primary production process, rather than peripheral issues such as energy use. Decision making may also be divided up between specialists, and global objectives may be replaced by tangible sub-goals whose achievement can be measured (Simon, 1959).

An interesting example of the importance of bounded rationality is provided by Coormans' (2009) review of the use of formal capital budgeting tools within investment decision-making. In contrast to the standard recommendation that investments with a positive net present value (NPV) should go ahead, she found that formal capital budgeting thickly typically played only a partial and secondary role within investment decision-making. Empirical studies showed that investment analysis was frequently conducted relatively late in the decision-making process and often served to justify decisions already taken. Instead, the key factor determining whether an investment went ahead was its contribution to the *strategic* objectives of the firm - including the extent to which it contributes to competitive advantage within the core business. This helps explain the observation that companies sometimes made negative decisions on profitable investments and positive decisions on non-profitable investment. Coormans argues that first, orthodox capital budgeting theory has little relatively little value in explaining investment decisions and instead plays a normative role; and second, that agency theory and transaction cost economics were insufficient to explain organizational behaviour. This conclusion seems questionable, however, since a focus upon strategic priorities (and a corresponding neglect of small, cost saving investments) is precisely what we would expect from boundedly-rational individuals.

Empirical studies of energy decisions generally support the hypothesis of bounded rationality (Sanstad and Howarth, 1994). For example, Stern and Aronson (1984) finds that consumers hold information on household energy use which is: '…not only incomplete, but systematically incorrect.' Similarly, the provision of accurate information on costs and benefits does not necessarily improve the quality of decision making. In a survey of energy information programmes, Robinson (1991) concludes that '... it is clear that, with the exception of some labelling programmes, energy information programmes on their own have not to date resulted in significant energy savings'. The implication here is that not only may bounded rationality provide an additional barrier to energy efficiency, it may also undermine the effectiveness of certain types of policy interventions Sanstad and Howarth (1994). If agents lack the time, capacity or skills to use existing information, there is little point in providing more information. This point is important as it directly contradicts the orthodox argument that intervention should be directed at correcting information market failures, rather than imposing performance standards. In practice, standards may be more effective in inducing energy efficiency improvements as they bypass the problem of bounded rationality (Sanstad and Howarth, 1994). Whether they are more cost-effective will depend upon the relative cost of the regulation compared to information programmes.

Routines as a response to bounded rationality

Within organizations, most decisions are likely to be the consequence of applying a set of rules and routines to a situation, rather than a systematic analysis of alternatives. As Stern and Aronsen note (1984) notes: ‘Organisations generally solve problems and respond to environmental demands by applying existing routines rather than developing new ones’. The simple payback rule can be considered as one such routine. While software packages allow rates of return to be calculated very easily, the payback rule may still have an advantage as it is simple and easy to communicate (DeCanio, 1994). Capital budgeting procedures could be considered a second type of rule, used in delegating the authority to spend money. Typically, the primary concern when evaluating an investment opportunity is whether there is money in the budget, rather than the rate of return (Stern and Aronsen, 1984). Expenditures that exceeds the budget (i.e. break the rule) require administrative approval, a potentially complex and lengthy process that discourages attempts to do so. Routines therefore facilitate information handling and minimise transaction costs, but can be inflexible.

A valuable example of the importance of routines is given by de Almeida’s (1998) study of the French market for energy efficient motors. When small end users had to buy motors in an emergency, the only parameters they considered were delivery time and price. The rule of thumb was to buy the same type and brand as the failed motor from the nearest retailer. Similarly, maintenance departments in large firms evaluated motors only in terms of maintenance costs and reliability, and ignored energy consumption. The split incentives barrier is partly responsible here, since maintenance departments are accountable for maintenance costs and process reliability, rather than energy costs. But de Almeida (1998) argues that that this barrier is reinforced by the time constraints on maintenance staff and their limited capacity to process information. This leads to the development of organizational routines that simplify motor procurement by ignoring energy efficiency. In this area, as in many others, split incentives and bounded rationality reinforce one another. The motor example also demonstrates the importance of analysing specific technology decisions, since the relative importance of bounded rationality may be expected to vary with the type of decision – for example between emergency replacement, routine replacement and new requirement.

Another example of routines comes from the construction industry, where designers rely heavily on simplified and outdated (but cognitively efficient) rules of thumb for sizing heating, ventilation and air-conditioning (HVAC) equipment (Lovins, 1992). This frequently results in equipment which is oversized in relation to the load, and which runs inefficiently on part load. Building designers rely on similar rules of thumb for acceptable capital cost per unit floor area, with the result that the potential trade-offs between capital and operating costs are overlooked (Lovins, 1992). Similar examples are to be found throughout engineering design, where professionals working to intense time pressures rely heavily on standardised designs (Lovins and Lovins, 1997).

Other types of rules and routines which may impact on energy efficiency include: operating procedures (such as leaving equipment running or on standby); safety and maintenance procedures; relationships with particular suppliers; design criteria; specification and procurement procedures; equipment replacement routines and so on. These may either be formally specified in written procedures or embedded in organizational practices. Since routines are a means of allocating attention, energy efficiency opportunities will receive little attention if they do not form part of standard routines and operating procedures. And to the extent that consideration of energy efficiency entails transaction costs or requires additional cognitive effort, in may easily be squeezed out by other priorities.

Inertia and the status quo bias

Routines can be surprisingly persistent and entrenched. For example, Fawkes and Jacques (1987) observed that staff in a brewery preferred to use an inefficient design of pump because it was 'easy to clean':

> '...Only after extensive tests and persuasive efforts did the brewers admit that it was just as easy to clean the more efficient pump...... the brewers exhibited an almost fanatical unwillingness to even consider change.'(Fawkes and Jacques, 1987).

This type of problem has been labelled *inertia* within the energy efficiency literature and identified as a relevant explanatory variable for the efficiency gap (Katzev, 1987; Stern and Aronsen, 1984). From an orthodox perspective, inertia does not constitute a recognised market failure and provides no grounds for policy intervention. But from a behavioural economics perspective, inertia is exactly what we would expect. First, we have the observation that gains are treated differently from losses. This means that opportunity costs will be undervalued relative to out-of-pocket costs, and foregone gains will be considered to be less painful than perceived losses. In the case of energy efficiency, organizations will consider themselves 'endowed' with their existing buildings, equipment and energy bill (Hewett, 1998). The potential savings in energy costs from energy efficiency improvements will be considered an opportunity cost, while the investment costs of energy efficient equipment will be considered an out-of-pocket cost. Loss aversion will therefore tend to bias individuals against making such improvements. As Thaler (1991) notes: '[A] certain degree of inertia is introduced into the consumer choice process since goods that are included in the individual's endowment will be more highly valued than those not held in the endowment ...'.

Second, we have the observation that individuals tend to be risk averse with respect to gains. In the case of energy efficiency investment, uncertainty over factors such as technology performance, reliability, lifetime and length of ownership will create uncertainty in the potential energy savings. In contrast, continuing with the existing 'endowment' is likely to give more predictable outcomes (Hewett, 1998). Since outcomes that are known with certainty will be given greater weighting than those that are uncertain, this will reinforce the tendency to inertia.

A third factor is the desire to minimize regret:

> 'Action and decisions require a greater justification than inaction, than failing to decide.….If our actions do not pan out, or cause a loss, we regret having acted. If, instead, we do not act, if we leave things as they are, and our investment does not pan out, or we lose, we still suffer regret but the regret is lesser.' (Piattelli-Palmarini, 1994)

All these factors may cause individuals and organizations to favour the status quo and to neglect potential improvements in energy efficiency, even when other market and organizational failures are absent. It is in this sense that cognitive biases may be considered as an additional barrier to energy efficiency. Rather similar conclusions were drawn by Stern and Aronsen (1984) in a review of behavioural research on energy efficiency. Stern utilized a theory known as 'cognitive dissonance' to conclude that: a) people tend to rationalize previous decisions, emphasizing the positive aspects of the decision and the negative aspects of the unchosen alternative; b) this tendency is greater for difficult, costly or irreversible decisions; and c) people remember the plausible arguments for their own position and forget the plausible arguments opposing their position. Hence people resist change because they are committed to what they are doing, and they justify that inertia by the downgrading of contrary information.

As Williamson (1989) argues, one of the functions of organizations is to economize on bounded rationality and mitigate such biases through the use of specialization. But while biases may be reduced, they are unlikely to be eliminated. Similarly, while competitive market pressures should help to squeeze out inefficiencies within private firms, the potential savings through energy efficiency may be relatively small compared to the other determinants of competitive advantage and hence may persist.[5] In practice, empirical studies of managerial decision-making have suggested that loss aversion and risk aversion may be even stronger than in the individual context (Swalm, 1966). Kahneman and Lovallo (1993) note that decision makers become more risk averse when they expect choices to be reviewed by others, while the rhetoric of prudent decision-making favours the certainty effect. For example, Swalm (1966) cites a manager who declined to pursue a project that had a 50-50 chance of either making US$ 300k or losing US$ 60k.

The above observations are generic – inertia may prevent the take-up of a wide range of opportunities, not simply those related to energy efficiency. But the important point is the effect of inertia on energy efficiency investment *relative* to that on purchasing energy as a commodity. This is analogous to the effect of imperfect information on energy efficiency investment relative to the purchase of energy commodities. In both cases, we would expect there to be a bias against energy efficiency and in favour of purchasing energy commodities. Inertia matters more for energy efficiency because it involves investing in hardware with uncertain outcomes and because it represents a departure from the status quo. Since energy efficiency and energy purchasing can provide alternative means of delivering the same energy service, this may be economically inefficient.

3.8 Contextual factors

The taxonomy of six barriers described above primarily relates to internal decision-making within the relevant organizations. But internal decision-making will be influenced by a range of broader, contextual factors that can either encourage or inhibit the adoption of energy efficient technologies - for example, the common practice of subsidizing energy prices can be a major disincentive to improving energy efficiency. Although these factors generally lie outside the direct influence of individual firms, they can impede the adoption of energy efficiency measures.

Some contextual factors directly follow from government policy, or the lack thereof. A common example is where government subsidizes the cost of energy to industry, or where a focus on energy supply policy undermines the motivation to address energy demand. Others relate to particular industrial sectors, such as the lack of standards and benchmarks and the limited scope for collaboration on issues such as energy management. Also relevant is the availability and price of energy efficient products and services in different countries and regions. Three developing country examples of such factors are: a) the lack of government support for awareness building inhibiting the adoption of energy efficient pumps and fans in China (CERF/IIEC, 2002); b) direct and indirect

5 It is an empirical question as to whether the potential savings are really small, or are merely perceived to be small. Lovins and Lovins (1997, p. 11) quote the example of a chief executive officer of a Fortune 100 company who stated that “I can’t really get excited about energy – it’s only a few percent of my cost of doing business.” But if the cost savings achieved by the energy manager at one of his company’s sites could have been reproduced throughout the company, it would have boosted the net earnings that year by 56 percent.

taxation on imported goods increasing the first cost differential between efficient and inefficient products in a number of developing countries (UNESCAP, 2001); and c) a combination of the lack of institutional capacity to implement energy efficiency programs, the neglect of energy efficiency within fiscal policy and the absence of performance standards for end use equipment all inhibiting the adoption of energy efficient air-conditioning equipment in China and Ghana (IEA, 2009).

Such contextual factors may either: increase the importance of one or more of the identified barriers to energy efficiency (e.g., the absence of energy labelling schemes making it more difficult and costly to obtain information on energy efficiency); make it more difficult to overcome barriers to energy efficiency (e.g., lack of institutional capacity preventing the introduction of labelling schemes); or introduce additional barriers of their own (e.g., tax treatment of imported goods making energy efficient products more expensive).

But the nature and relevance of such contextual factors may be expected to vary widely from one country, sector and technology to another and stakeholders may have different views on their relative importance. For example, in a study of voluntary agreements in China, Eichhorst and Bongardt (2009) found that government representatives placed much greater importance on providing technical assistance than did the industry representatives themselves. Studies of energy efficiency in developing countries typically highlight the absence of energy efficiency policies and programs to encourage awareness and training, the lack of a single agency or ministry with responsibility for energy efficiency and the prevalence of energy subsidies that undermine the business case for energy efficiency. Such obstacles may be challenging to overcome owing to the different interests involved. For instance, a number of studies have recommended the consolidation of Chinese steel and cement production within larger, more energy efficient firms, but this could have serious consequences for employment and regional politics.

3.9 Summary

This section has attempted to improve the understanding of barriers to energy efficiency by applying a number of concepts from economic theory. A ‘barrier’ was defined as a mechanism that inhibits a decision or behaviour that appears both energy and economically efficient. This term is widely used within the energy efficiency literature, but there is no consensus on how barriers should be understood, how important they are in different contexts, and how (if at all) they should be addressed. This makes barriers the subject of disciplinary disputes within academia and more fundamental conflicts within the politics of climate change.

The section began by introducing the concept of a barrier and the criticisms of the barrier model by orthodox economists. This led to a distinction between barriers and orthodox market failures and a recognition that some barriers may provide no grounds for policy intervention while others may prove too costly to overcome. The orthodox perspective may be criticized, however, for treating market failures as absolute rather than relative, for ignoring barriers which were internal to organizations and for adopting an unrealistic model of individual rationality.

The section then introduced six barriers to energy efficiency and explored the operation and consequences of these barriers in some detail. It argued that each barrier may be explained by more than one of the ideas discussed earlier and that several mechanisms may be expected to coexist. For example, hidden costs may result from search costs within product markets, organizational transaction costs and the costs resulting from interruptions to production. Similarly, restrictions on capital budgets may result from the financing risk of increased gearing, the agency relationships between central and divisional management, and the transaction costs of raising additional internal or external funds. The relative importance of each factor may be expected to vary between different technologies and organizations. Table 3.4 summarizes how these different barriers to energy efficiency may be understood from the perspectives of orthodox economics and transaction cost/behavioural economics.

Table 3.4 Understandingbarriers to energy efficiency using concepts from orthodox economics and agency theory, and from transaction cost and behavioural economics

Barrier	*Orthodox and agency perspectives*	*Transaction cost and behavioural perspectives*
Risk	Energy efficient technologies may be subject to higher technical risk Energy efficiency investments may be illiquid and irreversible, so the value of future benefits should be discounted more highly Energy efficiency investments may require a high rate of return to reflect the option value of delaying investment	Energy efficiency investments may have a high asset specificity and hence carry higher risks than other forms of investment Individual and organizational perceptions of risk may depart from those assumed in orthodox models and the resulting loss aversion may create a bias against energy efficient investment.
Imperfect information	Some types of information relevant to energy efficiency may have the features of a public good and hence may be undersupplied by markets. Since energy efficiency has the characteristics of a credence good, while energy commodities have the characteristics of a search good, there may be a systematic bias against the former. The search costs associated with identifying the energy consumption of products may be high, thereby creating a barrier to such purchases. In some circumstances, asymmetric information within energy service markets may lead to the adverse selection of inefficient products.	There will be transaction costs associated with acquiring, understanding and applying information. Bounded rationality ensures that these will be significant, even when information is freely available. The transaction costs of information acquisition may be high as a consequence of poor presentation, the lack of credibility of the source or the absence of interpersonal contacts.
Hidden costs	Some energy efficient options may be associated with hidden costs, such as disruptions to production. Some energy efficient technologies may perform poorly along other dimensions, such as reliability. The search costs associated with identifying energy efficient products may be high. Energy efficiency investments may need to recover 'overhead' costs.	The transaction costs associated with maintaining information systems, conducting energy audits, identifying opportunities, tendering, selecting suppliers, seeking approval for capital expenditures and so on may outweigh the potential savings in energy costs.

Access to capital	The cost of obtaining additional capital may exceed the average cost of the existing debt/equity mix, owing to the financing risk of increased gearing. Agency problems between shareholders and managers, plus the signalling associated with external financing may create a preference for internal finance and a reluctance to increase borrowing. Agency problems between central and divisional managers may lead to capital rationing as a form of control. There may be asymmetry between the risks and rewards of energy efficiency projects.	There will be transaction costs associated with obtaining additional funding from either internal or external sources, and these may be more significant for small, cost saving projects. The transaction costs of transmitting and assessing information on investment opportunities may inhibit optimal decision-making. Given severe constraints on time and attention, managers may focus on strategic investments and overlook small cost saving opportunities
Split incentives	For a range of reasons, individuals, departments or organizations may not be able to appropriate the benefits of energy efficiency investments	Transaction costs inhibit the development of shared savings contracts to overcome split incentive problems.
Bounded rationality	• N/A	Constraints upon time, attention, resources and ability to process information lead to the use of imprecise routines and rules of thumb, which may systematically neglect the small cost savings from energy efficiency improvements. Loss aversion and status quo bias contributes to inertia and the undervaluing of the benefits of energy cost saving relative to the out-of-pocket costs of investment. Risk aversion with respect to gains reinforces this inertia.

4 Summary of findings from recent empirical studies

This section summarizes some of the main findings from our review of recent *empirical* studies on barriers to energy efficiency – i.e., those studies that included either data gathered directly from interviews and surveys or from the meta-analysis of other studies. This includes a count of the number of times that each of the barriers in out taxonomy was mentioned within the sample, comments on the three most cited barriers, a discussion of how the obstacles faced by SMEs differ from those faced by large, energy-intensive industry and some brief policy implications. Section 4.2 looks in more detail at the problems faced by developing countries.[6]

4.1 Findings on barriers to energy efficiency

64 of the studies (40 percent of the total) were classified as *empirical* in that they included primary data gathered directly from interviews and surveys or from the meta-analysis of other studies. These studies provided information on barriers to energy efficiency, but the nature, amount and quality of this information varied widely from one study to another. The barriers that are identified and discussed in these studies have been categorized as far as possible according to the taxonomy indicated in Table 2.3. This necessarily involves some judgement, since the studies classify barriers under a wide range of (frequently overlapping) headings and most of them do not use the same taxonomy as in Table 3.1. Three commonly encountered problems were that:

Several of the barriers identified in a study mapped on to a single barrier within our taxonomy. For example, de Groot (2001) lists both 'energy efficiency has low priority' and 'energy costs are not sufficiently important'. These could be understood as examples of bounded rationality, where constraints upon time, attention, resources and the ability to process information lead managers to focus attention upon strategic priorities rather than small-scale cost saving (Cooremans, 2009).

A single barrier identified in a study could be interpreted in more than one way. For example, 'long decision chains' (Thollander and Ottosson, 2008) and '…a lack of coordination between different sections within our company' (Hasanbeigi, et al., 2009) could suggest either hidden costs in overcoming internal coordination problems or the widespread prevalence of split incentives, or both.

Barriers were identified that were not included in our taxonomy. For example, many studies highlighted broader, contextual factors such as 'lack of access to external technical support' (Shi, *et al.*, 2008).

[6] We also sought to examining the differences in terms of the prevalence and importance of barriers between those firms that mainly use energy for generic uses such as heating and lighting and those firms which use energy intensive production processes, as well as between those firms that were subsidiaries of multinational companies (or part of a joint venture) and those that were domestically owned. However, very few of the studies reviewed paid attention to these distinctions.

In many cases, these inconsistencies reflected a lack of rigour in conceptualizing barriers, the inclusion of factors that do not qualify as barriers under our definition, or the inclusion of factors that have little relevance for public policy. For example:

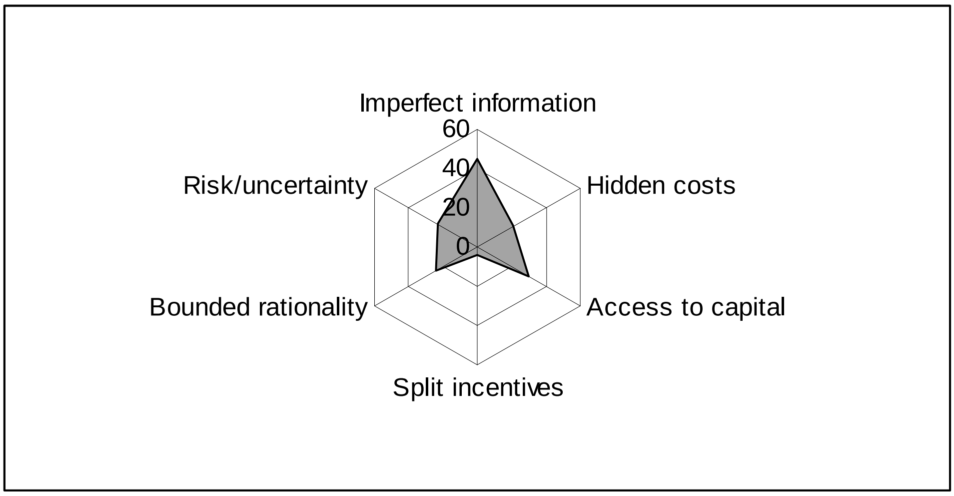
'organization is not aiming at a profit maximization' (Velthuijsen, 1993) is difficult to demonstrate empirically, provides little guidance on whether policy intervention may be justified (and what form it should take) and begs the question of why that is the case (i.e. the specific nature of the market and organizational failures); 'the government does not give incentives to improve energy efficiency', 'lack of enforcement of government regulations' and ' lack of coordination between different government agencies' fail to explain why cost-effective technologies are being neglected by individual organizations; 'concern about competitiveness' fails to explain why investments that should in principle improve competitiveness are not being made; and 'slim organization' (Thollander and Ottosson, 2008) is difficult to interpret without further explanation.

The main exception was the frequent reference to *heterogeneity*, which is where a technology that appears cost-effective on the average is not appropriate in a specific situation (Jaffe and Stavins, 1994).[7] This is a widely cited explanation for the 'energy efficiency gap' and the frequency with which it occurs in our sample of the empirical literature suggests that it is important. In general, however, the difficulties in classifying barriers point to the ambiguity of the concept and the fact that the relevant empirical phenomena can be classified and interpreted in multiple ways.

Having classified the relevant barriers within each study according to our taxonomy, we recorded the *number* of times that each of these barriers was mentioned within the sample of studies, thereby allowing a quantitative picture to be provided of the results. Although this is a crude procedure, the results provide some indication of the relative importance of each barrier in preventing cost-effective improvements in industrial energy efficiency. The results are summarized in Figure 4.1 and Figure 4.2. In addition, many of the individual studies implied a rank order in that some barriers were discussed more prominently than others. The implied importance of barriers for each individual study is captured in the database.

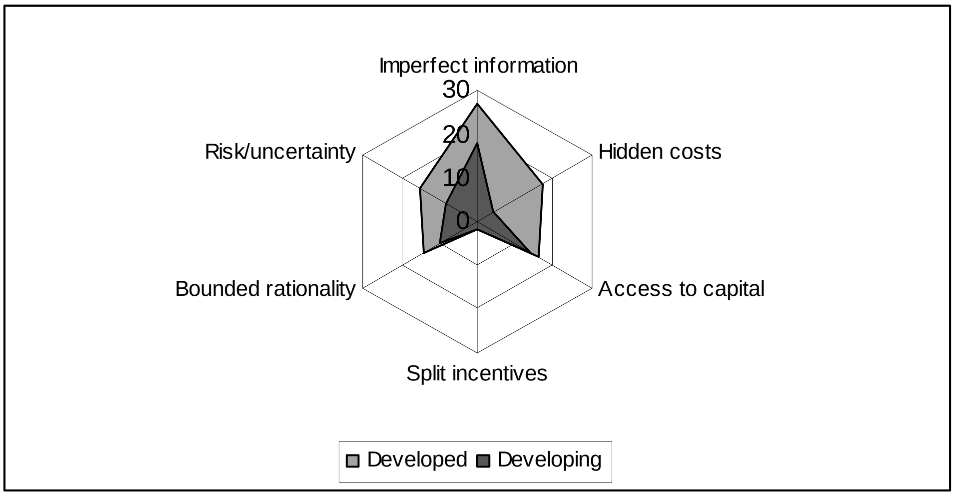
[7] For example, small scale CHP may be demonstrated to be cost-effective for medium sized sites in the brewing industry. But within this definition of a class of users, there may be wide variation in actual characteristics. In the case of CHP, profitability depends on high annual utilisation and typically requires at least two-shift, 6 days/week working patterns. While this may be the norm in a particular sector, it may not apply in all cases. Hence, for a subset of the population with low annual operating hours, CHP will not be profitable.

Figure 4.1 **Simple count of the number of mentions of specific barriers to energy efficiency within the sample of studies (n=147 references cited in 64 studies)[1]**



[3]The representation above is of a non-exclusive count in that most reports contain references to multiple barriers.

Figure 4.2 **Simple count of the number of mentions of specific barriers to energy efficiency within the sample of studies - distinguishing between developed and developing countries**



[1] 'Developing countries' predominantly means studies covering emerging economies in Asia, especially India and China. Developed countries are those in the OECD. Emerging economies refers to those studies which specifically identify one of the BRIMC countries, rather than overall developing countries or regions (e.g., Asia, Latin America) In the chart above, studies focused on developing and emerging economies are combined with those that focused on both developed and developing countries, or that do not address geographical context.

[3]The representation above is of a non-exclusive count in that most reports contain references to multiple barriers.

While all six of the barriers in our taxonomy appeared in the sample, the three that appeared most prominent were *imperfect information*, *access to capital* and *bounded rationality*.

Imperfect information

The frequency with which references to imperfect information appeared in the literature suggests a persistent view that managers would invest more in energy efficiency if they were more knowledgeable about the opportunities and the benefits. As a result, awareness raising and information programmes are repeatedly identified as priorities for public policy. Lack of information frequently coexists with inadequate skills and training, with the two factors tending to reinforce each other. Numerous papers pointed to the lack of information on current energy consumption owing to the high costs of measuring and monitoring (a form of hidden cost), the absence of adequate tools and procedures to account for economic benefits of efficiency improvements, the failure of the market to supply sufficient information on the energy performance of different products, the high cost of acquiring and using information on energy consumption, the tendency of contractual parties to exploit information asymmetries and the problems of adverse selection. In all cases, information problems coexisted with other barriers and both reinforced and were reinforced by those barriers. As a result, the information problems can be interpreted in a number of ways – most notably in terms of the hidden costs associated with acquiring information (Table 3.3). For example:

A survey of Swedish paper and pulp firms found that one third of the studied mills did not allocate energy costs to individual cost-centres by means of sub-metering. Instead, the costs were allocated on a square metre basis or some other crude measure (Thollander and Ottosson, 2009). As a result, the cost centres lacked information on their energy consumption and also lacked the incentive to reduce their consumption (split incentives). Whether the benefits of investing in sub-metering would outweigh the associated (hidden) costs are difficult to assess, but the fact that sub-metering is widely used in this sector suggests that it should be viable.

A survey by a US utility on the barriers to replacing forced air heaters with infrared heaters found that there were major difficulties in predicting energy savings given the wide range of variables that must be considered (Chen, 2007). The corresponding neglect of this technology could be interpreted as resulting from imperfect information on the associated energy savings, or from the risk that the energy savings will be less than anticipated or from the hidden staff and other costs required to conduct the relevant analysis.

A survey of the domestic Chinese market for pumps and fans found that it was dominated by products with low capital costs, low efficiency and high running costs (CERF/IIEC, 2002). The majority of end users were low wage agricultural workers who lacked information and awareness of the different options available and often were unable to assess running costs accurately. Chinese pump and fan manufacturers were able to provide efficient models at competitive prices but chose to concentrate these on the export market where demand for those models was greater. While imperfect information plays an important role here, the priority given to minimizing capital costs may also reflect difficulties in accessing finance among Chinese consumers.

A comprehensive survey of industrial, public and commercial organizations in Germany found the lack of information about energy consumption to be important barrier in seven out of the nineteen sectors examined (Schleich, 2009). The relevant sectors had low energy intensity, suggesting both that the (hidden) costs for measuring and monitoring energy consumption could be prohibitive and that employees in the sectors had less knowledge and expertise on energy related issues.

Bounded rationality

In many cases, the lack of information on energy efficiency is partly the result of time constraints and the pressure of multiple commitments which can undermine the efficacy of decision making. In this context, boundedly rational decision-makers will economize on cognitive resources by relying routines and rules of thumb. This can conserve time as a scarce resource, but may frequently result in energy efficiency opportunities being overlooked. For example, technological solutions may be routinely over-specified to exceed reliability criteria rather than optimized for efficient operation (Sorrell, 2003). Bounded rationality also contributes to risk aversion and leads managers to focus attention on strategic investments as opposed to more incremental energy efficiency measures. For example, turnover of equipment may be slower than optimal if an operational area is considered less than central to strategic planning. As with information problems, bounded rationality coexists with, reinforces and helps explain other problems such as split incentives (Table 3.4) and the observed phenomena can often interpreted in a number of ways. Examples occur throughout the studies reviewed and include:

A recommendation following a self-evaluation of utility-sponsored industrial energy efficiency initiative in Canada was to "……keep program procedures (including applications, measurement and verification) as simple and transparent as feasible to maximize participation and energy savings" (Tiedemann and Sulyma, 2009).

A paper presenting the case for energy management standards which observed that: "the energy savings potential of motor systems remains largely unrealized because it is deeply embedded in industrial operational and management practices" (McKane, et al., 2007).

Case studies of 48 organizations in the higher education, brewing and mechanical engineering sectors found repeated examples of staff making sub-optimal decisions owing largely to severe constraints on their time (Sorrell, 2000c; Sorrell, et al., 2004). The following quotations illustrate the problem:

"…When we replace a pump in that situation we are governed by the physical dimensions, the duty, and the cost. Probably no other questions get asked. Also, the decision wouldn't even get to me until it was time to sign the order. Very often the decision goes through the service unit or the supervisor. The foreman and supervisor would be the only people involved. It's normally an emergency situation. The existing one may be 30 years old and they don't make them anymore. We may have flanges with imperial measurements and new ones are metric - blah blah blah.....It's driven by need to replace it quickly. If one is available, get the same type as what's in at the moment. If not, get something that will physically fit. Energy efficiency just doesn't come into it...." (Sorrell, 2000b).

"Their prime focus is getting the product through and getting the quality right. To be honest, energy efficiency is at the back of their minds……..There are lots and lots of things where you think 'If you looked at so and so that would save us money' but you don't have time to follow it up." (Sorrell, 2000a)

Hidden costs

When assessing proposed energy efficiency projects, some factors may be well understood at the operations level within a plant while being less visible from outside. For example, temporary shut downs of machinery may be very unpopular with operations managers owing to the costs of lost production. Similarly, maintaining a capability to assess the benefits of energy efficiency on an ongoing basis will involve capital costs for energy information systems and ongoing costs for personnel to operate those systems. These costs are 'hidden' from the policy perspective and could partly explain the 'efficiency gap' identified by energy-economic models. The sample of studies provided repeated examples of such costs, with many studies highlighting how time constraints on staff prevented cost-effective opportunities from being taken up. While staffing levels could be increased, the associated costs could more than outweigh the saving in energy costs. Typical examples include:

A study promoting the non-energy benefits of energy efficiency investments found that: "…many projects will require process line shutdown during implementation, causing production losses. To gain credibility with the industrial sector, it is critical to be able to quantify both the upside and downside potential of proposed projects" (Pye and McKane, 1999).

A survey of 40 Swedish pulp and paper firms found that 'the cost of production disruption/hassle/inconvenience' was the second most cited barrier to energy efficiency (Thollander and Ottosson, 2008).

A survey of Thai cement firms found that 'the time required to improve energy efficiency' was the third most cited barrier, while a similar survey of Thai textile firms found the 'cost of production disruption' was the fourth most cited barrier (Hasanbeigi, et al., 2009).

Case studies of California cement companies found that the combination of limited staff time and concern about production interruptions were the major barriers to energy efficiency improvements, despite energy accounting for more than 10 percent of total costs (Coito and Allen, 2007). The study noted that keeping equipment operating and avoiding production disruptions was the highest priority, with kiln shutdowns being restricted to once a year to avoid stressing the ceramic insulation (Coito, et al., 2005).

Other barriers

The sample also provided numerous examples of *risk* and difficulties in *accessing capital*, but rather fewer examples of *split incentives*. Some illustrative examples include:

Risk: A survey of 40 Swedish pulp and paper firms found that 'technical risks such as risk of production disruptions' was the most widely cited barrier to energy efficiency, while a comparable survey of the Swedish foundry industry found that this was the second most important barrier (Rohdin, et al., 2007). Similarly, the US Industrial Technologies Program, building upon wide-ranging experience, found that low-risk, incremental change was greatly favoured over higher-risk transformational technologies (USDOE, 2008).

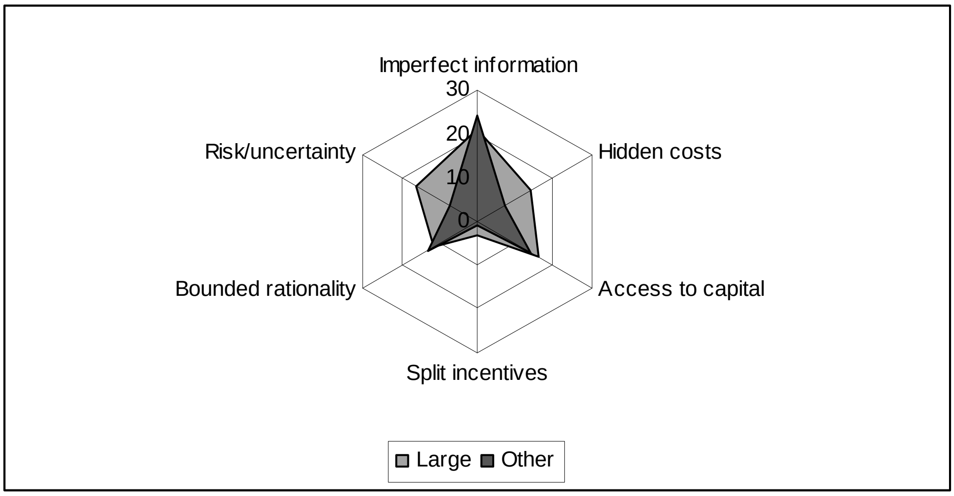
Access to capital: A study of the California cement industry found that many energy efficiency opportunities involved large capital investments and that most customers cite limited capital availability as a key reason why this had not been taken up (Coito and Allen, 2007). Similarly, a survey of 30 Swedish foundries found that 'access to capital' was the most important barrier to energy efficiency (and 'other priorities for capital investment' was the fourth), while a survey of 187 Norwegian food & drink companies found that 'lack of investment capital or capital needed for other priorities' was the second most cited barrier to energy efficiency (Helgerud and Sandbakk, 2009).

Split incentives: A study of compressed air systems in the EU found that the primary barriers were organizational, rather than technical, with multiple departments having conflicting objectives across finance, purchasing, production, operations and maintenance (Radgen and Blaustein, 2000). A study of motor systems gave comparable results, finding that: "…incentive structures within companies are frequently structured to reward lowest first cost rather than life cycle cost purchasing practices, which can impede motor system optimization" (McKane, et al., 2007).

Barriers in small firms

A common finding of the studies reviewed was that small and medium-size enterprises (SMEs) typically face greater obstacles to improving energy efficiency than larger firms. Figure 4.3 provides an illustration of the number of mentions of specific barriers in our sample of studies, distinguishing between large companies and SMEs.

Figure 4.3 Simple count of the number of mentions of specific barriers to energy efficiency within the sample of studies - distinguishing between large companies and SMEs[1]



[1] The 'Other' category includes studies focused on SMEs, SME-dominated sectors and studies that cover both large companies and SMEs.

The greater difficulties faced by SMEs have a number of origins. First, such firms are less likely to have the relevant information about energy efficient opportunities or the skills to implement those opportunities. They also face proportionately higher costs in obtaining data on energy consumption and costs and comparing this with relevant benchmarks. For many SMEs, energy forms a relatively a small portion of the total production costs and management pays little attention to energy efficiency. The neglect of cost saving opportunities may well be justified in these circumstances, as the time and resources required to identify and implement these opportunities would be greater than the energy cost savings achieved. Such firms may also be difficult to target through public policy, owing to their diversity and the lack of time, resource and expertise they have to apply to 'non-core' issues (Grubb and Wilde, 2005). SMEs can also be particularly cautious regarding where they undertake investments, as they cannot afford a capital loss. Hence, investment risk, whether arising from uncertainty about technical performance, energy prices or some other source, is likely to be a greater obstacle – and especially for large projects.

In addition, SMEs often face greater difficulties in obtaining capital, particularly in developing countries where capital markets are not well developed (Arquit Niederberger and Spalding-Fecher, 2006). Studies by The Energy and Resources Institute (TERI) of SMEs in the Indian foundry and glass industries indicated that limited access to capital was the major barrier to energy efficiency improvements. Many SMEs working in the glass industry in Firozabad (near Agra) were just barely continuing their operations (taking cost inputs and revenue generation into account), and had no way of providing the needed capital to make any investments. TERI therefore worked with the Swiss Agency for Development and Cooperation (SDC), providing financial and technical assistance for these SMEs (Pal, 2006).

Barriers in large, energy-intensive firms

Large energy-intensive firms have both greater incentives to improve energy efficiency and greater capacity to do so. Hence, the obstacles faced by such firms may differ in from those faced by SMEs. Recent studies of the cement sector illustrate these issues.

Energy consumption in the production and use of cement makes up a significant proportion of operations costs. Efficiency gains have been made over the past few years, partly in response to energy price volatility (AHAG, 2008; CSI, 2007). Since further reductions are both more costly and relatively less effective, organizational barriers become more influential. In a survey of US cement customers, Coito *et al.* (2005) found that the interviewees rated cost saving measures as a relatively unimportant contributor to their company's success.

> *"….When asked about the factors considered key to their business, customers all agreed that these factors were: environmental regulations, market conditions, and energy costs. However, when rating key factors to their company's success, identifying and implementing cost saving measures was low on the list" (pp.9).*

In contrast, the reliability and continuous operation of the plant was found to be of the highest priority, especially since shutting down a plant to install new efficiency-related equipment could jeopardize the integrity of the kilns. This suggests that managers' decisions on energy efficiency improvements reflect their localized assessments of the hidden costs involved.

The scale of energy efficiency projects in the context of other investments is also a significant factor. An energy-saving innovation may require operational and housekeeping improvements, incremental technological changes, retrofitting, or the introduction of completely new equipment and processes. The willingness to pursue these investments may depend on contemporaneous projects in the pipeline more than the returns of the individual proposal. For example, one firm indicated that they were investigating the feasibility of a complete plant overhaul, but uncertainty over this project had halted any possible efficiency projects (Coito, *et al.*, 2005). Large scale investment in energy efficiency therefore becomes more feasible when incorporated within an existing, strategic program to upgrade equipment and processes.

Access to capital also appears an important issue: "…many energy-efficiency improvements in the cement industry involve large capital investments for which limited capital was available" (Coito and Allen, 2007). However, the studies reviewed fail to provide sufficient analysis of *why* capital is restricted and the extent to which this reflects organizational problems or broader failures in the capital market (see Section 3.5).

Lack of information, skills and expertise is generally found to be less important for large, energy-intensive firms than for SMEs. But studies in the cement sector indicate that while firms have access to sufficient information they often have insufficient time to use this information – again highlighting the importance of hidden costs. Many firms were aware of the potential of smaller energy efficiency projects, but failed to pursue them because they "are not worth the trouble." and because they were preoccupied with "keeping things running" (Coito and Allen, 2007). The following quotation illustrates how time constraints and concern about production interruptions can combine:

> *"…..We have a strong emphasis on energy management. However, maintaining consistent production and product quality is the overriding concern. Although everyone at the plant is aware of energy and it is a key factor on which operations are based, we have limited operating staff. Fine-tuning for optimising efficiency, and developing, championing, and managing energy improvements takes staff time that is just not available given each person's day to day responsibility. We do have "special projects "engineering staff, but even they are too busy to take on energy projects that aren't related to maintaining production. Also, the plant must remain in production as much as possible. The interruptions and coordination required for retrofits can also restrict consideration of energy retrofits." (Coito and Allen, 2007)*

The industry's flagship voluntary reporting scheme – the Cement Sustainability Initiative –finds that the normal operational energy consumption of cement kilns was around 15 percent higher than the best performance achievable during commissioning tests - due to factors such as maintenance shut-downs and start-ups and variations in burning conditions and material humidity (CSI, 2007). While improving operational efficiency may be feasible, the hidden costs of monitoring performance and investigating and implementing new procedures can often outweigh the financial benefits. The CSI report also shows that substantial improvement in the average thermal efficiency of the sector depends upon the closure of old and inefficient kilns. While kilns in China, India, Asia Japan, Australia and

New Zealand are mostly of the most efficient type (preheater/precalciner ‘dry’ kilns), most of those in the CIS are older (‘wet’ kilns) and use up to 80 percent more energy per tonne of clinker produced (CSI, 2007). The lag in asset renewal in the CIS reflects the availability of cheap gas, undermining cost savings of switching to newer technology. Low energy prices, together with “complex and lengthy permitting procedures for new kilns, and lengthy court and appeal procedures" have also slowed the adoption of new kiln technology in North America (CSI, 2007). Hence, significant improvements in the energy efficiency of this sector will require these broader, market and contextual factors to be addressed, rather than internal organizational barriers. Such conclusions are likely to apply to many other energy-intensive industries.

Some of these contextual factors will more amenable to policy intervention than others. Where new generations of technology offer wider operational benefits, market mechanisms can be effective. For example, MNCs are shifting clinker production to Asia to take advantage of lower operating costs of dry kiln plants. Procurement policy to stimulate demand may also be effective in some contexts. For example, although composite cement is less energy-intensive to produce than the traditional product, customers are resistant to try unproven materials: "...there are still markets where cement and concrete standards and customer preference constitute a barrier to reducing the clinker-to-cement ratio" (CSI, 2007).

In sum, large, energy-intensive firms are typically better informed about energy efficiency opportunities than SMEs and face fewer difficulties in obtaining capital for investment. However, they still face important barriers to improving energy efficiency, most notably in relation to the hidden costs of staff time and the risk of production interruptions. The extent to which such problems could or should be mitigated through policy intervention is open to question. Nevertheless, the appropriate policy approach is likely to a significantly different to that for SMEs.

Contextual issues and policy implications

Many of the studies in our sample present results based on empirical observation at the level of industrial plants and many of these point to the need for more detailed data on the operational conditions in which technologies are implemented (Chen, 2007; Coito, *et al.*, 2005; Dupont and Sapora, 2009; Erpelding and Moman, 2005; Irrek, *et al.*, 2009; Ruth, *et al.*, 2001). Operations can be both highly localized and internally complex, suggesting the need for a system-level perspective to understand the energy implications of interactions between processes (Levacher, *et al.*, 2009; McKane, *et al.*, 2007; Pye and McKane, 1999). Complexity is also apparent at the macro level, for example between energy saving at the process level and the ‘embodied energy’ associated with energy efficient products (Irrek, *et al.*, 2009).

Success in energy efficiency hinges upon having adequate information about energy consumption and energy efficiency opportunities, together with the capacity to use information. The cost to the firm of obtaining such information data may constitute an important barrier. Performance labeling of energy-consuming goods and services is one way for policy to address such problems barriers. Sector performance benchmarks may also be effective in directing firms to adopt and achieve energy efficiency targets and collate more granular operational data. An integrated approach to overcoming informational barriers could also include a public repository of energy efficiency and operational data; certification, standardization and training; and an extension of labeling from products to processes (AHAG, 2008). But many proposals for overcoming organizational barriers are coalescing around the need for formal, standardized approaches to energy management systems (see Box 4.1). (e.g., Galitsky, *et al.*, 2003; Helgerud and Sandbakk, 2009; McKane, *et al.*, 2007; Motegi and Watson, 2005; Wroblewski, *et al.*, 2005). Such systems formalize energy management by establishing processes for regular energy audits and co-ordination of energy saving projects (CADDET, 1995). An EMS is typically founded on a company-wide energy policy with prominent support from senior management, as well as dedicated energy management personnel.

Box 4.1 Addressing internal barriers: Energy management systems and standards

Several studies contain empirical observation of positive impacts following the adoption of formal Energy Management Systems (EMS) (Helgerud and Sandbakk, 2009; Motegi and Watson, 2005; Thollander and Ottosson, 2009). Formal approaches are recommended as introducing energy efficiency into 'business as usual' operations, encouraging the diffusion of best practices and lowering the risk of investment projects (McKane, *et al.*, 2008).

This approach is currently being introduced via internationally-coordinated standards. Proposals for an Industrial Standards Framework combines energy reduction targets, energy efficiency standards, system optimization training, and documenting for sustainability. The aim is to link industrial energy efficiency with existing international ISO standards for quality and environmental management (McKane, *et al.*, 2008). The proposed Framework incorporates the established structures of ISO 9000 for quality management and ISO 14000 for environmental management, thereby building on the associated language, processes and culture of ISO compliance. The objective is to raise awareness of energy efficiency to the same level of prominence within the firm as established operational considerations such as costs, reliability, quality and throughput. By promoting a cultural shift within organizations, the benefits of energy management can be understood as intrinsically linked to other strategic goals. The Framework is also designed such that firms build internal capability through extensive training programs and anticipate the extension of carbon-related regulation by introducing transparency into systems for data collection and reporting.

As with the environmental management standard ISO 14001, the firm would commit to targets and an action plan that shows the procedures adopted in order to achieve them. However, criticisms have been expressed regarding whether the ISO standards-making process is representative of interests in developing countries. A second concern is that such standards could amount to trade barriers in some contexts as they require compliance that may be costly, and may not deliver the expected environmental benefits (Levy and Newell, 2005).

Highly localized conditions can often present a barrier to effective regulation and to diffusion of best practice within a sector. The prevalence of such heterogeneity supports the argument for market-based regulatory mechanisms such as carbon pricing to encourage innovation and technology adoption. However, many industrial facilities are relatively small energy users in absolute terms and so both fall below the size threshold for carbon trading schemes and are relatively unresponsive to changes in energy prices. A complementary approach is to introduce trans-national standards that build on existing processes and cultural dispositions within firms.

4.2 Findings on barriers to energy efficiency in developing countries

KOKO of the empirical studies related to firms in developing countries. Most of these stress the fact that the barriers to energy efficiency in developing countries are similar to those in industrialized nations but typically more pronounced. As indicated in

Figure 4.2, the most common barriers cited in these studies are *imperfect information* and *access to capital*.

Imperfect information

This barrier, as noted earlier, includes insufficient information regarding energy consumption and costs, energy efficiency opportunities and/or the relative energy performance of different technical options. In most cases, this is linked to time constraints, the cost of obtaining information and the lack of adequately trained personnel. While imperfect information is a generic problem, it appears particularly pronounced within developing countries and especially within SMEs. In many developing countries, there is insufficient capacity within the public sector for information dissemination and training which contributes to technical personnel being unfamiliar with energy efficiency opportunities and technologies (Worrell, *et al.*, 2001b). Examples of such problems include:

A study of motor systems in China which found that design engineers are "…..specialised in certain specific subjects…[and] tend to use existing or old products and equipment and are not aware of the latest energy efficient products" (EEPC, 2006).

A survey of 100 investors and users of intelligent motor controllers in China, which found that buyers were generally unaware of the energy efficiency potential of intelligent motor controllers (Yang, 2007).

A study of energy efficiency within Jordan which noted that the lack of awareness of the potential for energy savings was a key barrier to efficiency improvements (Arburas, 1989).

A study of the Chinese motor market which found that few enterprises were aware of the opportunities for reducing energy use through high efficiency equipment and system optimization, and those that were aware lacked the expertise to properly optimize their systems (Nadel, et al., 2002). Furthermore, the lack of expertise on system optimization within China made it difficult for the enterprises to gain appropriate advice.

An earlier study of the same market which found that the three key barriers to energy efficiency were: (1) a lack of system optimization information by enterprises and companies that use motors; (2) limited availability of energy efficiency experts to provide this information; (3) limited availability of printed information and other tools on motor systems benefits and approaches (UNIDO, 2000).

In many developing countries, the problem of lack of information is not confined to end users - many producers of end use equipment have little knowledge of energy efficiency opportunities and more limited access to the relevant technologies (Worrell, *et al.*, 2001b). In these circumstances, the information and knowledge deficits on both the production and demand side of the market can act to reinforce each other.

Access to capital

Studies regarding both large and smaller firms in developing countries underscored the importance of access to capital to implement energy efficiency projects and the frequent difficulties in doing so. The problem can be particularly pronounced for developing country SMEs where access to capital is frequently limited owing to factors such as the higher risk of lending to SMEs, the costs to the lender of establishing credit-worthiness, the lack of adequate securities for loans or the deficiencies of the domestic financial sector. SMEs typically have less access to international financing and hence rely more upon domestic sources of capital which may be less knowledgeable about technical risks and opportunities. In addition, the high inflation rates, political instability and corruption in many developing countries can increase the risks for domestic and foreign investors while national trade and investment policies can limit the inflow of foreign capital and technology. All these difficulties can reinforce the bias towards purchasing technologies with low capital cost and high running costs and encourage the purchase of inefficient, second-hand equipment (Worrell, *et al.*, 2001b). Our sample provided numerous examples of such difficulties, including:

A study of village enterprises in China found they had very limited access to capital because only two banks were allowed to have branches in rural areas (Worrell, et al., 2001b).

A study of the iron and steel industry in China found that the cost of capital was very high, so that once a firm had made an investment, it was difficult to instigate major changes (Worrell, 1995). This problem was reinforced by the longevity of capital-intensive process technologies in this sector (Moors, et al., 2005).

A study of financing for energy efficiency in China found that the government had barred lending to steel and cement companies in an attempt to prevent the unbridled expansion of heavy industry (Chandler and Gwin, 2007). This effectively blocked a pathway for energy efficiency finance. The study also found that numerous rules discouraged foreign direct investment, domestic banks were not permitted to lend money at interest rates of more than ~8 percent thereby encouraging them to be risk-averse, and the limits on the annual growth of loans had undermined the effectiveness of ‘Green Loan’ programmes for energy efficiency improvements (Yanjiaa and Chandler, 2009).

A study of the Chinese market for motors in fans, pumps & compressors highlighted the high relative cost of imported technology and the lack of access to capital (EEPC, 2006). An earlier study of the same market found that enterprises frequently lacked the capital to pay for optimization projects or more efficient products while domestic motor and equipment manufacturers lacked capital for purchasing equipment and higher quality raw materials that could help improve the efficiency of their products (Nadel, et al., 2002). In each case, the difficulty in accessing capital is exacerbated by the reliance upon imported technologies.

A study of small breweries in Bolivia found that their profitability and difficulties in accessing finance were preventing them from converting to from wood-firing to natural gas from wood (van Oosterhout, et al., 2005).

Other barriers

Developing country studies provide numerous examples of other barriers but few studies attempt to evaluate their relative importance. As observed above, the different barriers are commonly interdependent and most could be interpreted in a number of ways. Some relevant examples include:

Split incentives: A study of energy efficient motor systems in China noted that the purchasers of motors are generally not the end users (Yang, 2007). This creates a conflict between the motivations and decision criteria of the purchaser (e.g., to minimize the up-front capital cost) and those who pay the energy bill.

Bounded rationality: Numerous studies find that energy efficiency is typically a low priority within firms, due to lack of senior management engagement on the issue (Ozturk, 2005; Worrell, et al., 2001a). Firms frequently exhibit ‘inertia’, meaning they are reluctant to make changes and adopt new technologies for a variety of reasons (Clark, 2000).

Contextual issues and policy implications

Many of the studies indicated possible reasons why the barriers faced by developing country firms – and especially by SMEs - are more pronounced. These include: the fragmentation of industry and the poor links between SMEs and other groups of firms (including foreign-owned subsidiaries); the limited availability of relevant knowledge and skills, many of which need to be imported; the tendency to rely upon ageing, second-hand equipment; the dominance of family enterprises which can frequently restrict access to skills and information; and the reliance upon imported technology, combined with the limited capacity to adapt and use that technology.

Of particular importance was the widespread prevalence of subsidized energy (and particularly electricity) prices which acts to undermine the economic case for improved energy efficiency (Lohani and Azimi, 1992; Park and Labys, 1994).[8] While the general view was that subsidized energy prices in developing countries served as a barrier to energy efficiency, it is important to point out that these barriers can be context, industry and technology-specific. For example, in a study examining the effectiveness of an energy efficiency loan program to Indian firms, the majority of firms complained about the government's electricity subsidies to agriculture and low-income households, which led to higher electricity prices for industry. The result was to encourage industrial users to generate their own electricity using small-scale plants that were less energy efficient than the large centralized plants supplying the National Grid (Yang, 2006).

Many developing countries make no coordinated efforts to promote energy efficiency, whether in the form of an agency devoted to energy efficiency within the federal government or a division or section within their energy ministries. Hence, the problems such as lack of information remain unaddressed. However, there are some recent and encouraging examples within this area among the emerging economies such as China and India (see Box 4.2).

[8] That said, debates continue regarding the most effective way to address subsidized energy prices. For instance, there has been mixed success of the reform of the energy sector of developing countries through privatization (which generally recommended a market price for energy). This was the mantra offered in the 1990s / 2000s through the 'Washington consensus'. Although some suggest that its failure was due to governments implementing these recommendations half-heartedly, others purport that the 'prescriptions' offered were too generic, not taking contextual aspects sufficiently into account (Ockwell, *et al.*, 2009).

Box 4.2 Energy efficiency policies and programmes in China and India

Energy efficiency is the first priority of China's energy policy in its 11th Five-Year plan (2006–2010). The Chinese government initiated the "1000 enterprises programme", whose goal is to reduce the emissions of 1000 large companies by the equivalent of 260 million tonnes of CO_2. The firms involved account for one third of total Chinese energy consumption total and almost half of industrial energy consumption. Some government agencies also have procurement programs requiring energy efficient products.

In June 2008, the Government of India released their National Action Plan on Climate Change (NAPCC). The Plan consists of Eight Nations Missions, where India will target its efforts to address climate change. One of these, the National Mission on Enhanced Energy Efficiency (NMEEE), includes four new initiatives, namely: a) a market based mechanism to enhance cost-effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded; b) accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable; c) creating mechanisms that would help finance demand side management (DSM) programs in all sectors by capturing future energy savings; and d) developing fiscal instruments to promote energy efficiency.

In addition, the Mission also proposes sectoral initiatives, including: a) restructuring of subsidies in the fertilizer sector so as to provide adequate incentives to undertake energy efficiency investments; b) promoting technology up-gradation in the SME sector by developing sector specific programs for different industry clusters; and c) accelerated depreciation and reduced VAT for energy efficient equipment.

The document recognizes the need for technology transfer, financing mechanisms and capacity building and especially the knowledge gap that exists in the micro, small and medium enterprises (MSME) sector. It proposes the development of sector-specific programmes for technology development and adoption in such industries.

The Action Plan is still at an early stage and it remains to be seen how successful it will be. It has a number of weaknesses, however, including the lack of detail in certain areas and the neglect of the largest energy consumer, namely local and national government.

Although less prominent in the sample of studies reviewed, a final theme was the importance of *technology transfer*. This goes beyond simply importing a technology (e.g., a production process) and includes improving a firm's technological capabilities and 'absorptive capacity', defined as "…the ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990; Park and Labys, 1994). Studies espousing this view suggest that barriers to the adoption do not only rest with lack of information, but also lack of knowledge, understanding and capacity.

Technology cooperation can only be successful if it "takes place as part of a wider process of technological capacity building" (Ockwell, *et al.*, 2009). In other words, technology cooperation must include opportunities for learning, with successful adoption requiring the ability to innovate (Douthwaite, 2002). But opportunities for learning are not sufficient to ensure successful cooperation, players must also be able to assimilate and make use of this new knowledge (van den Bosch, *et al.*, 2003). While there is no single agreed upon definition for technological capabilities, a common view holds that they are assets, including human resources, technical and scientific skills and infrastructure, held by a firm, region or country that facilitate technological change (Rogers, 2003). Several of the studies reviewed highlighted these issues, but captured them as a lack of training, expertise and information. However, as indicated above, addressing technological capabilities and absorptive capacity are distinct issues, warranting a specific policy response.

Related to this are those studies that highlighted the importance of communication between different groups (Rohdin, *et al.*, 2007; Vine, 2005). For instance consultants or energy service companies (ESCOs) can be advantageous as they can provide expertise and the time needed to devote to energy efficiency issues, but often there is a lack of trust and confidence between industry firms and these consultants. As a way of overcoming this trust barrier, one study highlighted a programme from the US DOE where university students served as an external resource to provide energy audits to SMEs. After being involved with firms for some time, some firms opted to hire the student to have their own internal energy efficiency resource (Tonn and Martin, 2000).

5 Summary of findings from a selection of detailed studies

A number of the studies were especially useful in that they attempted to identify the relative importance of different barriers to energy efficiency in different contexts. This was achieved either through the econometric analysis of survey data (e.g., Schleich, 2009) or (more usually) from the less formal analysis of survey and interview data (e.g., Hasanbeigi, *et al.*, 2009). As with the full sample of studies, this subgroup classified barriers in a variety of overlapping and often inconsistent ways, with most of them conceptualizing barriers from the viewpoint of the industrial firms rather than economic theory. Also, several of the studies are methodologically weak and/or include factors that do not qualify as barriers under our definition. Nevertheless, a brief review and comparison of these studies can provide some useful insights into the relative importance of different barriers in different contexts. The following sections summarize each study in turn.

5.1 Barriers in non-energy-intensive firms in Germany

One of the few methodologically rigorous studies of this topic is the econometric analysis of 19 public, commercial and industrial sectors by Schleich and Gruber (2008). This data source for this study was a survey of 2848 companies and public sector organizations conducted in 1999 – an impressively large sample size for a study of this type (Geiger, *et al.*, 1999). The survey included detailed questions on the implementation of energy saving measures, together with perceptions of barriers to energy efficiency. Energy costs as a share of total costs was relatively low for all of the sectors interviewed, but they nevertheless accounted for around 17 percent of German final energy consumption.

The organizations were classified as being 'active' on energy efficiency if they had adopted at least 50 percent of the measures that were deemed feasible. This formed the dependent variable (active=1; inactive=0) in a Logit model which was estimated separately for each sector. The dependent variables include the size of the organization, its annual energy consumption, the split between thermal energy and electricity consumption and the responses to questions about barriers to energy efficiency. The following barriers were included in the specification, with the text in brackets indicating how they map on to our taxonomy.

- Lack of information about energy-efficient measures (imperfect information);
- Lack of time to analyse energy efficiency potential (hidden costs);
- Other investment priorities (bounded rationality);
- Energy costs may vary in the future (risk);
- Organization space is rented (split incentives).

The main findings were as follows. First, the relative importance of each barrier varied widely from one sector to another, but in the majority of cases multiple barriers were found to be statistically significant. Second, non-profit sectors experienced the most barriers, while the most energy-intensive experienced the least, but the variation in energy costs within sectors made little difference. Third, the *split incentives* barrier – in the classic landlord-tenant form - was statistically significantly more than half the sub-sectors, although the majority of these were in the public and commercial sectors rather than the industrial sector. Fourth, *imperfect information* was found to be statistically significant in one third of the sectors, but the survey did not allow any inferences to be made about whether this was due to inadequate metering or other organizational deficiencies. Also, information problems were less important in the industrial sectors, perhaps owing to greater technical expertise. Finally, both *risk* related to future energy prices and *hidden costs* in the form of time constraints were found to be relatively unimportant, with these variables only being statistically significant for two sectors in each case.

The relative unimportance of time constraints is a surprising result and conflicts with the findings of comparable studies such as Sorrell *et al.* (2004) (see below). Time constraints may contribute to the lack of information on energy efficiency measures since the organizations may lack the time to investigate those opportunities. Such a result would appear as a correlation between these two independent variables, but in most of the sectors analysed the correlation coefficient was well below 0.5.

5.2 Barriers in Dutch industry

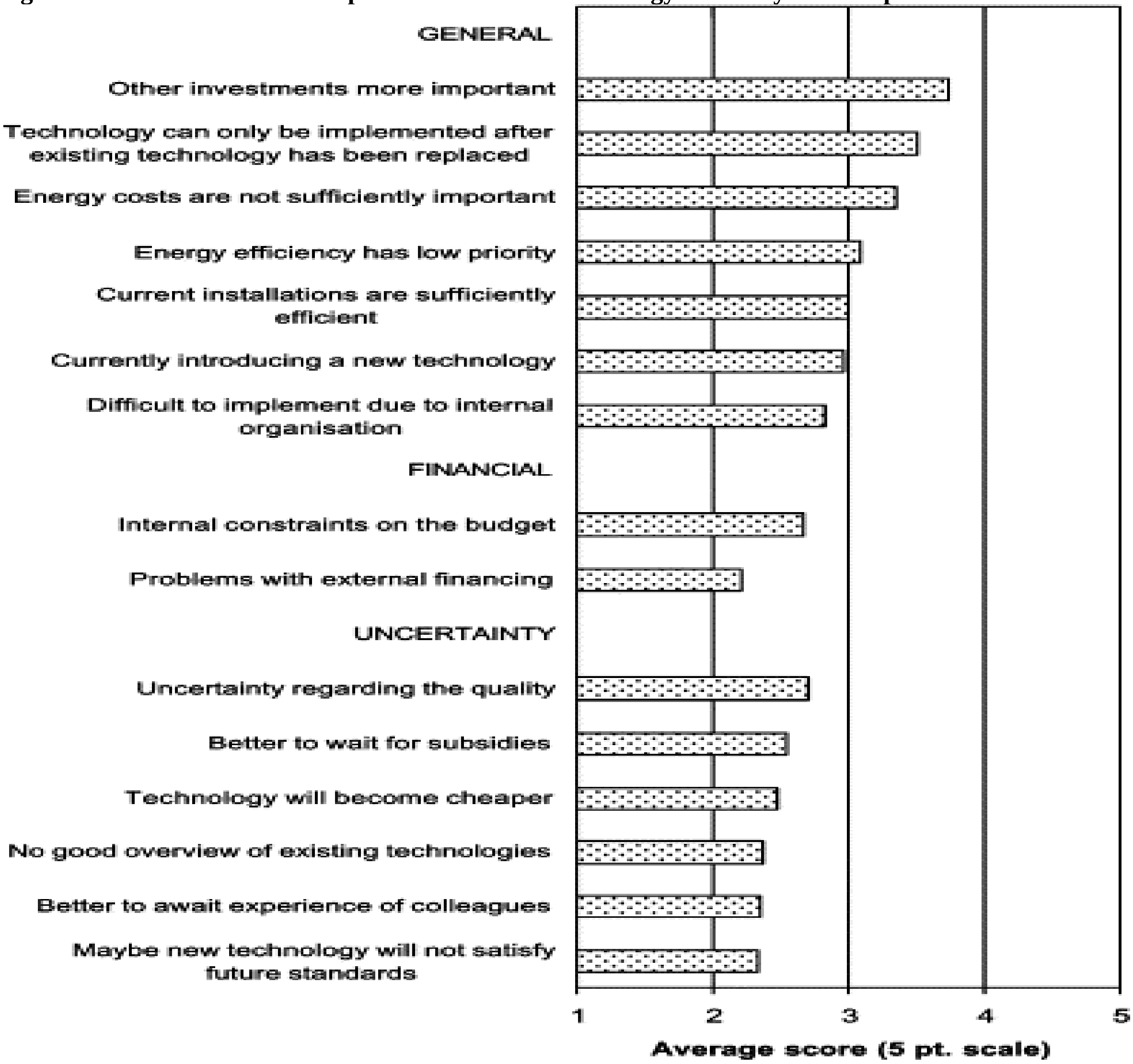
One of the earliest econometric studies of this topic was by Velthuijsen (1993), who administered a survey to 70 Dutch firms from seven industrial sectors, including a mix of small and large firms within each sector. All of the firms indicated potential energy efficiency gains, although the reported size of these gains was significantly lower than that indicated by energy-economic models. This could reflect a lack of knowledge of efficiency opportunities, a more accurate assessment of the hidden costs associated with those opportunities or a mixture of the two. The firms were asked to what extent they had installed various energy efficient technologies and whether seven potential barriers to energy efficiency were relevant to them (either yes or no). Chi-squared tests were then used to assess whether 'poor performers; differed from the population in the frequency with which they cited the importance of a particular barrier.

The barriers found to be significant were: a) the small size of the energy bill (*hidden costs*); b) limited knowledge (*imperfect information*); c) non-core business (*bounded rationality*); d) equipment is not scrapped yet; and e) budgetary constraints (*access to capital*). Four of these map relatively straightforwardly onto our taxonomy, while 'equipment is not scrapped yet' suggest that the investment would be uneconomic. However, the methodology did not allow the relative importance of these variables to be assessed, or the determinants of each to be explored in more detail.

A comparably comprehensive study was conducted by de Groot *et al* (2001) who administered a 15-page survey to a wide range of Dutch companies. Econometric analysis was used to determine how investment behaviour, barriers to investment and responsiveness to policy intervention varied with firm characteristics and sector. The sample included 135 firms in the chemicals, metals, machinery, food, paper, horticulture, construction and textile industries.

The authors identified three groups of barriers to energy efficiency: general barriers related to the overall decision-making process; financing constraints (*access to capital*); and those related to various types of uncertainty (*risk*). The overall ranking of these barriers is illustrated in Figure 5.1. As with other studies, the categories are both ambiguous and difficult to interpret within our framework.

Figure 5.1 The relative importance of barriers to energy efficiency in a sample of Dutch firms



Note: Barriers given 5 points if considered 'very important' and 1 if considered 'totally unimportant'.

The results show that the most important barrier for firms was the existence of other investment opportunities that are either more profitable or considered more important (opportunity cost). Also ranked highly was the incomplete depreciation of the existing capital stock and the fact that 'energy costs are not sufficiently important'. Both of these could be taken as implying that *hidden costs* outweigh the energy cost savings. The 'general' barriers were ranked more highly than those related to *access to capital* and *risk,* but the former includes both factors suggesting economically rational behaviour (e.g., 'currently introducing a new technology') as well as those suggesting organizational failures (e.g., 'difficult to implement due to internal organization'). While the authors conclude that the results show a 'decision-making process that is rational and consistent with cost benefit analysis' the data seems insufficient to demonstrate this is the case.

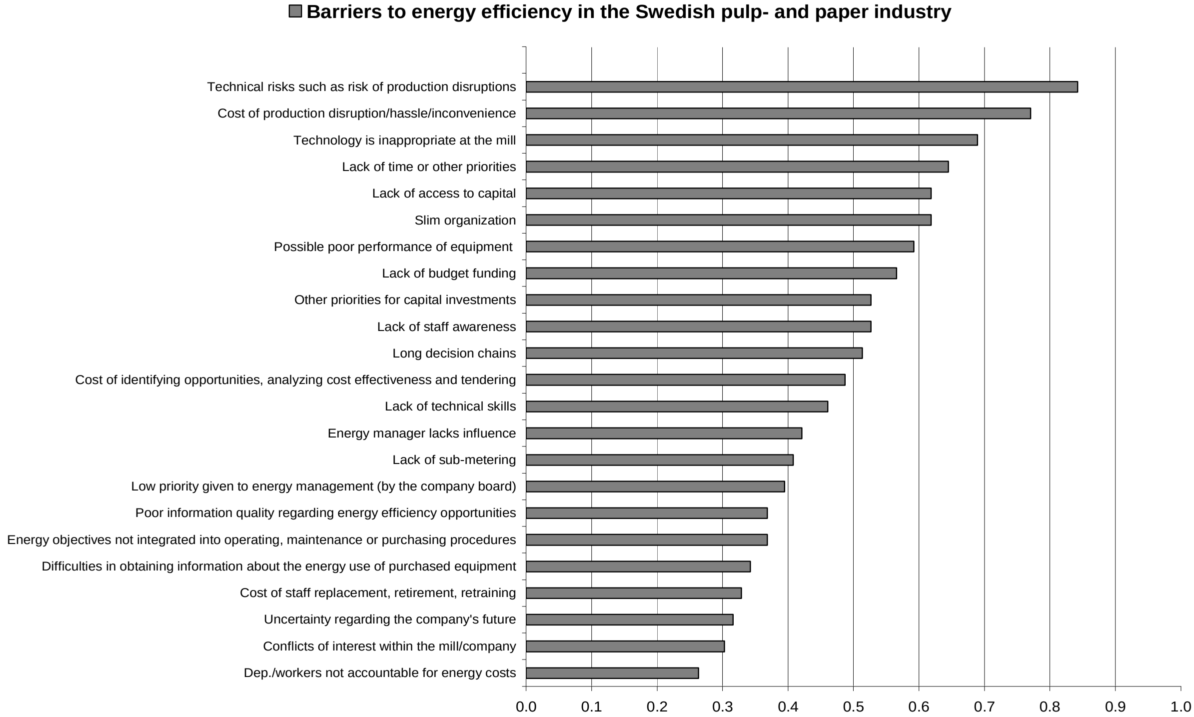
The authors found evidence that sector- and firm-specific factors helped explain investment behaviour and attitudes to policy, although the analysis was limited by the number of observations. The most important factors were firm size, energy intensity and competitive position. Only a few of the barriers were given a significantly different ranking by different sectors, but ‘general’ barriers were less important in energy-intensive firms and more important in large firms facing strong competition. While the importance of *imperfect information* was not investigated, the survey found good knowledge of energy efficiency opportunities in large firms that invest heavily and are faced with strong competition, but less knowledge in small firms facing limited competition and spending relatively little on investment. Overall, the results suggest that policies such as information programmes should be targeted at particular categories of firm.

5.3 Barriers in the Swedish pulp and paper industry

Thollander and Ottosson (2008) analysed energy management practices in the Swedish pulp and paper industry. The sector was chosen for its high energy intensity, accounting for nearly half of Swedish industrial energy use (or ~2 percent of EU-25 industrial energy use). The authors cite studies suggesting investments with payback periods of less than two years could reduce electricity consumption in this sector by 1-4 percent and heat consumption by 10-15 percent. The sector is very capital intensive, using continuous processes that produce paper at speeds of ~100km/h, with a result that disruptions to production are costly and changes to the production process can be risky.

Thollander and Ottosson sent a questionnaire to the energy managers of 59 paper mills and received 40 replies (a 68 percent response rate). The survey contained questions on the relative importance of different barriers, using the framework originally developed by Sorrell *et al.* (2000c). It also examined the drivers to improved efficiency, the investment criteria used and the method of energy cost allocation. The responses to the question on barriers are summarized in Figure 5.2.

Figure 5.2 The relative importance of barriers to energy efficiency in the Swedish pulp and paper industry



Note: Barriers given 1 point if considered of major importance, 0.5 points if sometimes important and zero points if rarely important.

The respondents identified the risk of production disruptions as the most important barrier to energy efficiency, while the cost of production disruptions/hassle/inconvenience was rated second. Both of these could be interpreted in terms of the *hidden costs* of investment (production disruptions, staff time) as well as the *risks* associated with any new technology that affects the core production process. This demonstrates that investments which involve interruptions to the main production process may be associated with significant hidden costs and hence may only be viable if the project can be completed within the normal scheduled downtime or as part of a larger investment project. This is consistent with earlier findings for the cement industry (Section 4.1) and is likely to be a common situation in many energy-intensive industries.

The third most important barrier was 'technology inappropriate at this site' (*heterogeneity*) while 'lack of time or other priorities' was found to be the fourth. The latter could again be interpreted in terms of *hidden costs*, although reinforced by the *bounded rationality* of the decision makers. From this perspective, all four of the most important reasons for neglecting opportunities to improve energy efficiency in this sector could be interpreted as rational behaviour from the perspective of the firms – either because the technology is inappropriate at the site or because the associated (hidden) costs and risks of the investment outweigh the potential energy cost savings. However, as in all studies of this type, it remains unclear whether the costs and risks are being accurately assessed and whether there may be scope for improvement – for example, in increasing staffing levels to reduce time constraints. The same comment applies to the fifth most important barrier, lack of *access to capital*, since neither the reasons for capital restrictions nor their rationality were assessed.

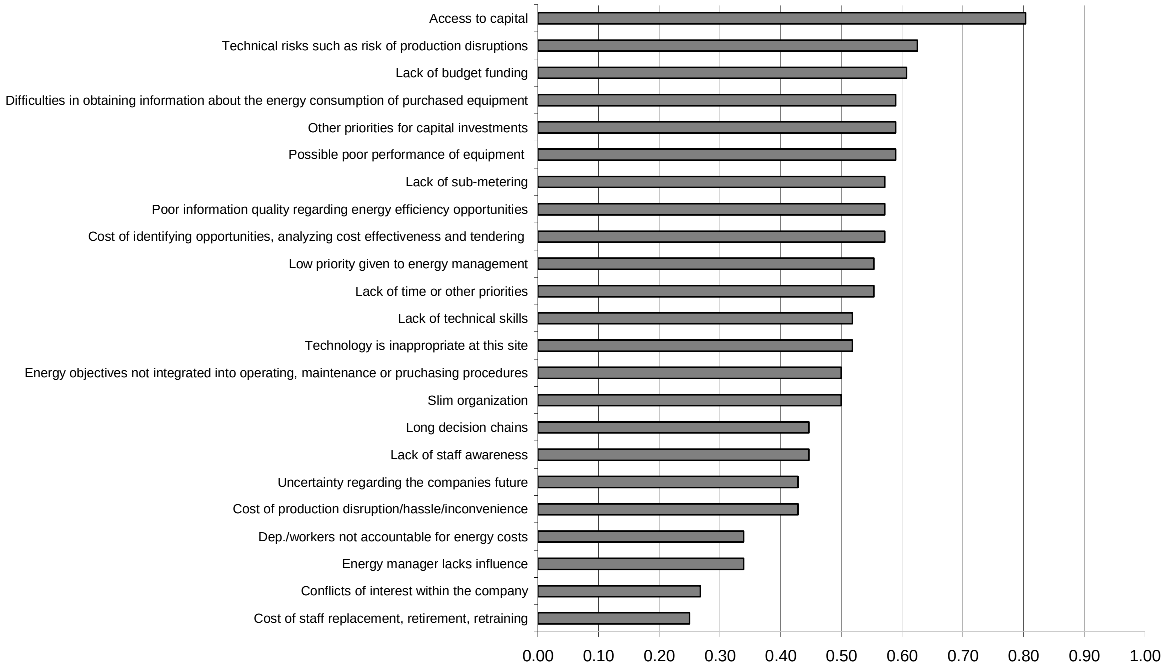
Barriers that appeared relatively unimportant in this sector included *imperfect information* - for example regarding the energy performance of purchased equipment or the opportunities for improved efficiency; and *split incentives*, where the lack of accountability for energy costs was ranked in the least important. This is probably because the firms are large with technically competent staff and because two thirds of the sample allocate energy costs to departments using low-level sub-metering (Thollander and Ottosson, 2009). These features appear likely to be characteristic of many energy-intensive industries.

5.4 Barriers in the Swedish foundry industry

Rohdin *et al* (2007) also draw on the Sorrell *et al* (2000c) framework in their analysis of barriers in the Swedish foundry industry. This is a fairly energy-intensive sector, with the average number of employees ranging from 65 for privately owned companies to 113 for group owned companies. The Swedish industry is electricity-intensive compared with other European foundries, perhaps as a result of the comparatively low electricity prices that existed prior to market liberalization.

Rohdin *et al* (2007) sent a questionnaire to 20 executives at each of 59 members of the Swedish Foundry Association, obtaining a response rate of 47 percent. The respondents claimed that cost efficient energy efficiency measures existed at 93 percent of the sites. Their responses to the question on barriers are summarized in Figure 5.3.

Figure 5.3 The relative importance of barriers to energy efficiency in the Swedish foundry industry



Note: Barriers given 1 point if considered of major importance, 0.5 points if sometimes important and zero points if rarely important.

The most notable result from this survey was that limited *access to capital* was found to be significantly more important than the other barriers listed – in notable contrast to the findings for large firms in the pulp and paper industry (Section 5). This is not surprising, since over two thirds of the sample had experienced negative profits in the last three years. Although this seems likely to make the companies more risk averse, uncertainty regarding the future of the firm was not considered a major obstacle to efficiency improvements. Also, the firms were reluctant to consider third-party financing as a solution to this problem.

The next five barriers were considered of fairly equal importance and were, in descending order, risk of production disruptions (*hidden costs*), lack of budget funding (*access to capital*), cost of obtaining information (*hidden costs* and *imperfect information*), competing priorities for capital investment (*access to capital* and/or *bounded rationality*) and possible poor performance of equipment (*risk*). Oddly, ‘departments not accountable for energy costs’ was considered relatively unimportant, despite being a necessary outcome of the ‘the lack of sub-metering’ which was considered an important obstacle.

The ownership of the company was found to make some difference to the assessed importance of different barriers. While access to capital was a dominant issue for all foundries, independent companies faced more informational problems while group-owned companies appeared to face more constraints as a result of monitoring and control provisions (e.g., long decision chains, lack of budget funding). These same provisions may also contribute to the stricter investment criteria (1–3 years payback) used by these companies (DeCanio, 1998).

5.5 Barriers in the Thai cement and textile industry

Hasanbeigi *et al.* (2009) surveyed six large companies in the Thai cement industry (which is relatively energy-intensive) and 28 SMEs in the textile industry (which is not).[9] The questionnaire was based on six core questions, each with several options for response. The respondents indicated their level of agreement with these options on a five point scale. Supplementary interviews were also conducted with independent experts, including policy makers, regulators, and energy services companies.

Table 5.1 indicates how the industry respondents and experts perceived the five most important barriers to energy efficiency. The text in brackets suggests how these categories map onto our taxonomy, but (once again) interpretation is difficult and a number of the categories are ambiguous. Also, several of the categories (e.g., lack of enforcement of government regulations) do not constitute barriers under our definition.

[9] The authors acknowledge that the textiles sample was biased towards those with a pre-existing interest in energy efficiency given that firms were selected from the membership of an industrial energy organization.

Table 5.1 Highest ranked barriers to energy efficiency in the Thai cement and textile sectors

Textile industry	*Cement industry*	*Experts*
1. Management finds production more important (*bounded rationality*)	1. Management concerns about the investment costs of energy efficiency measures (*hidden costs*)	1. Management concerns about other matters especially production rather than energy efficiency (*bounded rationality*)
2. Technology will become cheaper (*risk*)	2.Management finds production more important (*bounded rationality*)	2. Lack of financial resources especially in SMEs (*access to capital*)
3. Maybe new technologies will not satisfy future standards (*risk*)	3. Management concerns about time required to improve energy efficiency (*hidden costs*)	3. Lack of top management commitment/understanding/vision (*bounded rationality*)
4. Cost of production disruption is high (*hidden costs*)	4. There is a lack of coordination between external organizations (*not relevant*)	4. Lack of information and knowledge in companies especially in SMEs (*imperfect information*)
5. There is a lack of coordination between different sections within our company (*split incentives?*)	5. Current installations are sufficiently efficient (*?*)	5. Lack of enforcement of government regulations (*not relevant*)
6. The government does not give financial incentives to improve energy efficiency (*not relevant*)		6. Lack of coordination between different government agencies (*not relevant*)

The results show how the perceptions of barriers differ across the three categories of interviewee. In the cement industry, the three highest ranked barriers may all be interpreted in terms of *hidden costs* – a key theme being the overriding importance of maintaining production. In contrast, the respondents from the textile industry appear more concerned about technical *risk* – a point that was also highlighted in the expert interviews. Despite the fact that the textile firms are much smaller than the cement firms, they had a greater concern about lack of coordination between different departments.

The expert interviewees attached more importance to the lack of financial resources (*access to capital*) than did the industrial respondents, especially for SMEs. However, the textile firms (mostly SMEs) highlighted this indirectly in asking for financial support for efficiency improvements. The expert interviewees were also the only group to highlight the importance of *imperfect information*. Nevertheless, when asked what is required to improve energy efficiency, all three groups gave top priority to more information and training.

A theme common to all three groups was the low priority given to energy efficiency by top management (*bounded rationality*). This suggests that raising the awareness of top management must form a key component of successful energy efficiency policy.

5.6 Barriers in Greek industry

Sardianou (2008) investigated decision-making on energy efficiency in 50 Greek firms in the metals, machinery, food and drink, chemicals, paper and textiles sectors. The survey contained questions on the physical and economic characteristics of the firm, energy consumption and costs, investment behaviour and routines, knowledge and implementation of energy efficient technologies and perceptions of barriers to energy efficiency. The study uses a rather idiosyncratic classification of barriers which is not rooted in a clear theoretical framework. Partly as a result of this, the results are difficult to interpret.

The results show that knowledge of energy efficiency opportunities did not vary widely between sectors, but tended to be greater in large firms, in those with a greater proportion of skilled staff and in those that invested more heavily. Of the 21 barriers to energy efficiency listed in the questionnaire, the most important were found to be:

- Bureaucratic procedures to get governmental support (does not explain the neglect of cost-effective opportunities);
- Increased perceived cost of energy conservation measures (not clear whether this is due to hidden costs or some other factor);
- Limited access to capital (access to capital);
- Slow rate of return of the investment (not clear whether this is due to hidden costs, overly strict investment criteria or some other factor);
- Financial resources are spent on other investment (bounded rationality);
- Uncertainty about future energy prices (risk).

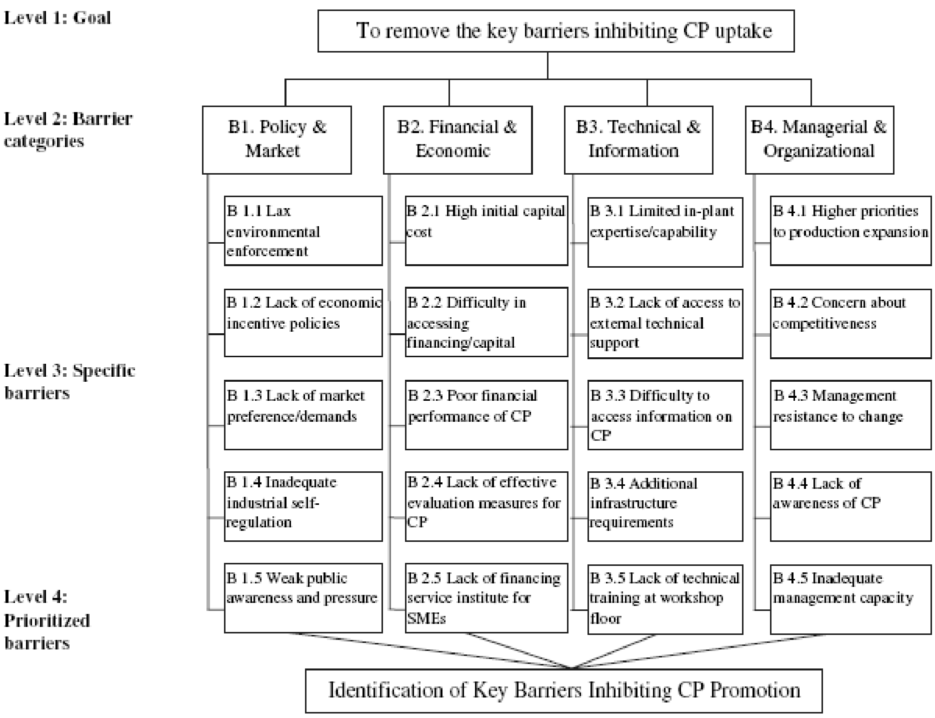
Sardianou used probit models to investigate how the survey responses varied between sectors and found that sector characteristics influenced the barriers to energy efficiency – and by implication, the appropriate policy response. However, the picture was complex and led to few clear recommendations. Barriers related to imperfect information were found to be less important for large firms (measured by floor area and a number of employees) and those with a more highly qualified workforce. Oddly, these firms also considered lack of access to capital to be a more significant problem, as did more energy-intensive firms. An important need was identified for investment in training and associated diffusion of information in Greek industry.

5.7 *Barriers in Chinese SMEs*

Shi *et al* (2008) use a novel *analytic hierarchy process* (AHP) methodology to explore how different stakeholder groups (government, industry and independent experts) perceived and ranked barriers to the adoption of 'cleaner production' technologies by Chinese SMEs. This sector was chosen because of its low level of adoption of such technologies and because of the particular problems it faces, including: resistance of key decision-makers, limited skills, difficulties in obtaining technical information and limited access to capital (Shi, *et al.*, 2008).

The AHP method reduces complex, multi criteria decisions into a set of pair-wise comparisons that are easier for respondents to perform. In this case, the comparisons related to the relative importance of different barriers to the adoption of 'clean' technologies - including energy-efficient technologies. The results were then processed in an algorithm that assigned an appropriate weight to each barrier and calculated a rank order. An important objective of the study was to investigate barriers that were both 'internal' and 'external' to the firms. A list of 20 'specific' barriers were identified and grouped into four categories, namely: policy and market; financial and economic; technical and information; and managerial and organizational (Figure 5.4.). The survey was circulated to 300 stakeholders, of which 119 responded, but only 65 passed a consistency test.

Figure 5.4 Categorization of barriers to energy efficiency used in the study of Chinese SMEs



Source: Shi *et al* (2008)

The respondents considered the *policy and market* barriers to be the most important (normalized global weight of 0.347), followed closely by *financial and economic* barriers (0.334). The aggregate weights assigned to the other two categories (*technical and information* and *managerial and organization*) were less than half of those assigned to the first tow. The authors labelled the two prominent categories as being ‘external’ to SMEs and the two less prominent categories as being ‘internal’, but this distinction is problematic. At the level of individual barriers, the six most prominent were:

- lack of economic incentive policies (0.099);
- lack of environmental enforcement (0.095);
- high initial capital cost (0.082);
- poor financial performance of technology (0.076);
- Difficulties in accessing capital (0.067);
- Weak public awareness and pressure (0.057).

Three of these (1, 2 and 6) fail to explain the neglect of cost-effective opportunities, but may be of greater relevance to ‘clean technologies’ more generally, the adoption of which is more dependent upon government regulation. The latter comment also applies to the fourth and possibly the third barrier on the list, while the fifth highlights the difficulties faced by SMEs in accessing capital. Hence, from the perspective of cost-effective energy efficiency opportunities, *access to capital* appears the most prominent barrier for Chinese SMEs, while from the perspective of clean technologies more broadly, wider range of considerations apply.

The stakeholder groups were broadly consistent in their ranking of barriers, with the differences perhaps reflecting their different expertise and focus. For example, the experts gave greater weight to ‘policy’ barriers while industry itself gave greater weight to ‘financial’ barriers. Interestingly, none of the groups placed a high importance on the lack of information and awareness, suggesting a policy focus on capital markets and investment subsidies may be more appropriate.

5.8 Barriers in the brewing and mechanical engineering sectors in Ireland, Germany and the UK

Sorrell *et al* (2004) remains the most in-depth and comprehensive investigation of barriers to energy efficiency and their approach has since been adopted by a number of other authors (e.g., Masselink, 2007). The project involved detailed case studies of energy management practices in 48 organizations in the brewing, mechanical engineering and higher education sectors in Ireland, the UK and Germany. Each case study involved detailed interviews with several employees, supplemented by postal surveys, documentary analysis and interviews with sector experts. The focus was the decision making procedures relevant to energy efficiency and the reasons for the neglect of energy efficiency opportunities. The potential barriers to energy efficiency were classified as described in Section 2.

Interviewees confirmed the existence of an ‘energy gap’, with the majority of case study organizations, identifying cost-effective measures with very short payback periods that were routinely passed over. The ‘gap’ was found to be somewhat smaller in the brewing sector which is more energy-intensive and hence has a greater incentive to improve efficiency. For each sector in each country, the individual barriers to energy efficiency were classified as either of high, medium or low importance. The results are summarized in Table 5.2 and Table 5.3.

Table 5.2 Barriers considered to be of high importance in the brewing and mechanical engineering sectors in Germany, Ireland and the UK

Barrier	*Brewing*	*Mechanical Engineering*	*Total*
Hidden costs	U G I	U G I	6
Access to capital	U G I	U G I	6
Imperfect information	U	G I	3
Risk	U G	U G	4
Split incentives	U G		2

Note: U= UK case studies; G = German case studies; I = Irish case studies

Table 5.3 Specific instances of barriers considered to be of high importance the brewing and mechanical engineering sectors in Germany, Ireland and the UK

Barrier	*Specific instance*	*Brew*	*Mech*
Hidden costs	Overhead costs of energy management	U G I	U G I
	Cost of gathering information, identifying opportunities, etc.		G I
	Cost of production disruptions	U	
	Loss of utility	G	
Access to capital	Capital budgeting procedures within the organization	U I	U G I
	Availability of capital to the organization	U G I	U
Imperfect information	Lack of information on organizational energy use	U	G I
	Lack of information on energy efficiency opportunities		G I
Split incentives	Equipment purchasers not accountable for energy costs	U G	
Risk	Business risk	U G	U
	Technical risk associated with energy efficient technologies	U G	

Note: U= UK case studies; G = German case studies; I = Irish case studies

Sorrell *et al* found that problems associated with *hidden costs* and *access to capital* was the primary reason for not investing in energy efficiency. But in general, hidden transaction costs appeared to be significantly more important than either hidden production costs or loss of utility (see Table 3.3). The costs associated with lost production only appeared relevant for a subset of energy efficiency opportunities in the brewing sector, while examples of the *hidden benefits* of energy efficiency technologies greatly outnumbered examples of the loss of utility associated with such technologies.

The hidden cost that appeared by far the most important was the *overhead costs of energy management*, including the cost of employing skilled energy management staff. These costs proved difficult to quantify, but strong evidence of their importance was provided by the severe time constraints on survey respondents and interviewees in all the case study sectors. These constraints applied to all sizes of organization, but were particularly evident for smaller mechanical engineering firms. Interviewees emphasized how time constraints were the primary reason they were unable to keep up to date with technical information, identify energy efficiency opportunities and implement energy efficiency projects. In most cases, time constraints were considered more important than capital constraints – 'if we had more money, we wouldn't have time to spend it!'.

While it proved hard to judge whether individual organizations were allocating sufficient staff time, three points were clear. First, most of the case study organizations appeared to be allocating significantly less staff time than is recommended in best practice publications (i.e. one full-time energy manager for each £1 million of annual utilities expenditure); second, the staff time devoted to energy management varied widely between organizations of comparable size in the same sector with comparable opportunities to improve energy efficiency; and third, the costs and benefits of staff cuts – including lost opportunities from improved energy efficiency – did not appear to have been adequately assessed. Since most of the case study organizations had not conducted comprehensive energy audits, they lacked relevant information on what these costs and benefits were. Furthermore, where energy management staff had access to this information, it was rarely communicated effectively to senior management who generally lacked interest in energy issues. As a result, the latter remained ignorant of the cost saving opportunities that were available.

Problems with access to capital applied at two levels: insufficient capital through internal funds combined with the reluctance to raise additional funds through borrowing or share issues; and the low priority given to energy efficiency within internal capital budgeting procedures. The first of these applied to practically all the case study organizations and derived in part from the difficult business situation faced by many. For example, the brewing industry was facing declining demand, overcapacity, increased competition and reduced margins and was responding with cost cutting drives, staff reductions and site closures. The net result was a shortage of internal funds for capital investment which was then restricted further by priority setting within internal capital budgeting procedures, coupled with rigid budgeting rules which make it difficult to transfer funds from one area to another. Since energy costs were small and energy efficiency projects could be postponed, they typically fell to the bottom of the priority list. Management attention was focused instead on strategic areas such as expansion of production, or on non-discretionary projects such as essential replacement of equipment.

Capital rationing was implemented through both strict limits on capital budgets and stringent investment criteria, although the first of these appeared more important. Very few organizations came near the best practice recommendations of a dedicated energy efficiency budget equal to 5 percent of the annual expenditure on utilities and the majority had no such budget at all. In contrast, while investment criteria were strict, they were often chosen by the engineering department itself, rather than being imposed by senior management. It was repeatedly emphasized that the majority of energy efficiency improvements resulted from new or replacement investments undertaken for reasons other than reducing energy costs, so an overemphasis on dedicated energy efficiency projects would be inappropriate. Similarly, it was generally the case that additional investment could not be undertaken without further staff resources to implement those projects. Hence, the results suggested that that capital constraints – whatever their origin – were largely secondary to hidden costs in inhibiting energy efficiency improvements in these sectors.

5.9 Summary

A number of factors make it difficult to draw general conclusions from these studies, including the range of methodological approaches used, the diversity of approaches to classifying barriers and the interdependence between these categories. For example, the opportunity costs identified by de Groot in 2001 may be interpreted as an information problem (lack of awareness of potential benefits) or a hidden cost (more apparent to managers than to external analysis). The notion of relative importance is itself open to interpretation, such as whether this applies at the level of the firm or the sector.

Most of the studies take just one response to a survey question as encapsulating the barriers experienced for the firm as a whole. The results are therefore contingent upon the phrasing of the question and the perspective of the respondent, including their position within the company. The main exception is Sorrell *et al* who conduct multiple interviews in each case study organization and hence are better able to distinguish organizational barriers (such as those between functional departments) as well as obtaining greater insight into the nature of each barrier (such as what form the constraints on capital take and why this is the case). The tendency for barriers to interact and thereby reinforce each other is also difficult to capture within a survey and requires a more qualitative approach.

Nevertheless, it is possible to establish the two ‘most important’ barriers identified by each study and these are summarized in Table 5.4. This analysis shows that *hidden costs* (in various forms) and difficulties in *access to capital* are the most common explanations for the energy efficiency gap. The (hidden) overhead costs of energy management – as reflected in the time constraints on staff - appear to be an important issue for the majority of firms, while the risk and cost of production disruptions are important for energy-intensive firms. Difficulties in accessing capital appear of greater importance for SMEs. Several studies take the prevalence of hidden costs as indicating that the firms are behaving rationally in neglecting energy efficiency opportunities. But since this is difficult to demonstrate, the conclusion is as much ideological as it is empirical.

Two other conclusions from these studies are that: first, multiple barriers typically coexist and reinforce one another; and second, contextual factors matter a great deal, including the operation of capital markets and the extent of government promotion of energy efficiency. Difficulties with the former and the relative absence of the latter are a particular focus of concern in developing countries.

Table 5.4 Summary of findings from the detailed studies

Study	*Method*	*Key barriers*	*Comments*
German SMEs	Econometric analysis of survey (n=2848)	1. Imperfect information 2. Split incentives	Most firms were SMEs and were not energy-intensive. Multiple barriers coexist, with significant variation between sectors
Dutch industry	Survey (n=135)	1. Hidden costs	Investment behaviour influenced by firm size, energy intensity and competitive position Authors conclude that decision making is rational and consistent with cost-benefit analysis
Swedish pulp and paper industry	Survey (n=40)	1. Hidden costs 2. Risk	Large, energy-intensive firms Risk of production disruptions of particular importance. Neglect of opportunities may largely because technology inappropriate or hidden costs outweigh benefits
Swedish foundry industry	Survey (n=28)	1. Access to capital 2. Hidden costs	Small, energy-intensive firms facing economic difficulties Monitoring and control problems with group-owned companies
Thai cement and textile industry	Survey (n=6 for cement, 28 for textiles)	1. Hidden costs 2. Risk / Access to capital	Cement firms large and energy-intensive while textile firms small and non energy-intensive Hidden costs (especially production disruption) more important for cement. Risk and access to capital more important for textiles
Greek industry	Survey (n=50)	1. Hidden costs 2. Access to capital	Significant variation between sectors and size of firm. Information problems less significant for large firms
Chinese SMEs	AHP analysis of survey (n=65)	1. Access to capital	Contextual factors important
Brewing and mechanical engineering	Case-studies (n=48)	1. Hidden costs 2. Access to capital	Brewing firms have medium energy-intensity, while engineering firms have low energy intensity Most important barrier was the (hidden) overhead costs of energy management, as reflected in the severe time constraints on staff. Capital constraints had numerous sources and were largely secondary.

6 Main findings

The main findings from this study are as follows:

Hidden costs are real, significant and form the primary explanation for the 'efficiency gap'

Barriers to energy efficiency are understood, classified and interpreted in multiple ways and the lack of both rigour and consistency in the empirical literature makes it difficult to interpret. Nevertheless, many of the identified barriers can be understood as 'hidden costs' - that is, costs that are only poorly captured by energy-economic models. These include, for example, the costs associate of maintaining energy information systems, conducting energy audits and distinguishing between efficient and inefficient products. These hidden costs frequently outweigh the potential saving in energy costs - especially in SMEs with low energy intensity – and thereby form the primary explanation of the efficiency gap. What remains in dispute is the extent to which such costs may be cost-effectively reduced by organizational initiatives, public policy or a combination of the two. While hidden costs are inherently difficult to investigate, much of the existing research is of poor quality and our understanding of hidden costs remains poor. Future research needs to be better informed by economic theory, employ more rigorous methodologies and investigate new approaches, such as comparative studies of 'good' and 'bad' performers that seek to explain the reasons for success.

The neglect of energy efficiency opportunities is overdetermined

Hidden costs generally coexist alongside one or more of the other barriers in our taxonomy. For example, lack of information pervades energy service markets and senior management in industry is frequently unaware of the opportunities available. This coexistence of multiple barriers has a cumulative effect, with the result that the neglect of energy efficiency opportunities becomes overdetermined. This implies that efforts to remove one barrier may only be partially successful if other barriers remain. For example, individual departments could be made accountable for energy costs through investment in submetering and energy information systems, combined with changes in budgeting procedures. But if the departments lack the skills, information or capital to respond to these incentives, or if time-constrained individuals have more pressing priorities, the net effect may be very limited. Hence, the key issue is not so much the relative importance of different barriers, but their cumulative effect. Initiatives to encourage cost-effective investments will need to understand and address several aspects of the problem if they are to be successful.

Barriers to energy efficiency in developing countries are similar to those in developed countries, but more pronounced.

Problems of lack of information and skills are widespread in developing countries and inadequately addressed through public policy, while difficulties in accessing capital are very common, especially for smaller firms. What this is partly a consequence of hidden costs (e.g., the cost to the lender in establishing credit worthiness), it tends to be exacerbated by the deficiencies of the financial sector in many developing countries, including more limited knowledge of technical risks and opportunities combined with trade and investment policies that restrict access to foreign capital. These problems should be a priority for reform, alongside the removal of energy subsidies which undermine economic case for improved energy efficiency.

A targeted policy mix is required

Barriers to energy efficiency are multi-faceted, diverse and often specific to individual technologies and sectors. This implies that effective policy solutions will need to address the particular features of individual energy service markets, the circumstances of different types of energy-using organization, and the multiple barriers to energy efficiency within each. As a result, it is likely that a *policy mix* will be required, in which several different initiatives work together in synergy. For example, while carbon taxes may create price incentives to improve energy efficiency, the response will be muted in many sectors unless steps are taken to lower transaction costs. Conversely, if such steps are not taken, carbon pricing may need to be unacceptably high to have a significant impact on energy demand. The basic elements of this mix are well established in developed countries and include best practice schemes, demonstration projects, training initiatives, market-based instruments, labelling schemes and minimum standards for the energy efficiency of equipment.

The costs and benefits of these individual instruments will require careful analysis, as will the overall coherence the policy mix. To date researchers have paid too much attention to modelling what could be achieved and too little attention to evaluating what policy has (or has not) achieved - and why. While the required methodologies are well established, applications to energy efficiency policies are relatively rare (Frondel and Schmidt, 2001; Meyer, 1995; Sorrell, 2005; Train, 1994). Perhaps the most intensively studied area is utility demand-side management (DSM) programmes in the US, where some of the better studies suggest that energy savings are significantly overestimated and costs underestimated (Joskow and Marron, 1992; Loughran and Kulick, 2004). However, in a comprehensive review, Gillingham *et al.* (2006) concluded that DSM programmes appeared to be cost-effective, although concerns remained about hidden costs for consumers. Also, the ‘free-rider’ effect was in part balanced by ‘free-driver’ effects and some of the better designed programmes performed significantly better than the average. Gillingham *et al.* also concluded that US appliance standards were cost-effective, and would remain so even if the hidden costs were equal to those included in the evaluation. Such ex-post evaluations should be a priority for future research.

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Telephone: (+43-1) 26026-0, Fax: (+43-1) 26926-69
E-mail: unido@unido.org, Internet: www.unido.org